IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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COMING MEETINGS AND PAPERS

PHILADELPHIA SECTION

Saturday, October 1st, 1927

"Motor Rollers—A New Individual Motor Drive With the Motor Self-Contained in the Roller," by A. M. MacCutcheon, Engineering Vice President, Reliance Electric & Engineering Company, Cleveland, Ohio.

Engineers Club
1317 Spruce Street

Dinner 6:00 P. M.
Meeting 7:30 P. M.

Everybody Welcome

BIRMINGHAM SECTION

Saturday, October 29th, 1927

"Manufacture of Carbon Brushes," by W. C. Kalb, Technical Engineer, National Carbon Company, Cleveland, Ohio.

Meeting will be held in the Bankhead Hotel, Birmingham, Ala.

Everybody Welcome

Saturday, November 26th, 1927

"Steel Mill Roller Motor," by A. M. MacCutcheon, Engineering Vice President, Reliance Electric & Engineering Company, Cleveland, Ohio.

Meeting will be held in the Bankhead Hotel, Birmingham, Ala.

Everybody Welcome

CHICAGO SECTION

Thursday, October 20th, 1927

"Inspection Trip to Gary Tube Company, Gary, Ind." Followed by Discussion.

Everybody Welcome.

PITTSBURGH SECTION

October, 1927

"Inspection Trip to Pilger Tube Mill, Pittsburgh Steel Company, Allenport, Pa." 150 of our Active members have been invited by the Pittsburgh Steel Company to inspect their new Pilger Seamless Tube Mill. Should you desire to take part in the trip which will be held the latter part of October, please write to the Association offices after which time an official pass, along with other details, will be mailed to you.

EDITORIALS

"THE ORDER OF STEEL MILL ELECTRICAL OPTIMISTS"

When the first steel mill was placed in operation, it was realized that mechanics would have to be employed to keep the machinery "ready for service," and also to make repairs as breakdowns occurred. As other mills were built, similar positions were created so that each one had its crew of repairmen to look after the maintenance of the machinery. The chief of these groups of mechanics was usually given the title of "Millwright," and in most cases was a graduate machinist. These were the days when steam, water and air were the prime movers employed, and this Millwright was a past master in knowledge of all their working parts. His position was one of importance for upon him rested the responsibility of having the mill in operating condition. This type of organization has existed for many years, and the millwright or master mechanic has been the most "depended upon" man in the organization.

When the first electrical drive was installed on a mill, its operation and control involved problems that the millwright could not solve, and this particular piece of machinery was placed under the care of an electrician. Then additional electric drives were installed until, at the present time, this type of prime mover is responsible for the operation of the mills—and steam, water and air occupy only subordinate positions. This responsibility for the operation of the electric drives rests with the mill electrician, and the millwright has left only the mechanical end of the mill—but in the eyes of most managements, the Master Mechanics and Millwrights still cling to the prestige and position they gained in years gone by, and the electrical inspector occupies a subordinate position outside the operating fraternity.

However, there has been a gradual revision of opinion among the operating men on the value of these electrical inspectors. If you are a mill man, just look for a few examples similar to those following for a proof. When an operation is too slow or too fast, does the millwright figure on new gears, or is his first thought to see if the motor speed can be changed? If there are some broken teeth in a gear wheel, a galded bearing, or any other of the many things that can cause a faulty operation, and the operator just knows there is something wrong, watch if he does not "blow" for the electrician first. Next time you have a motor driven pump in trouble, watch for the first man called on the job regardless of what the trouble might be, or if one of your mills is so tight the motor cannot start it, see if "electrical trouble" is not the first diagnosis. Then, for the next six months, take an inventory of the number of times the electrical man is called on jobs and locates mechanical trouble rather than his own, and for his big heartedness gets credit with the delay—just because he was the one to answer the call. And you might also check how your men scheme, plan, and hustle to get jobs done, and compare with similar jobs done by the millwrights who belong to the operating fraternity. Look over your inspectors, and examine them for a knowledge of rigging, the machinist trade, carpentry, concreting, operating the mill, and mechanical designing, in addition to their electrical knowledge, and then compare their position to that of the millwright.

After you do all these things, you can apply for admission to the "Order of Steel Mill Electrical Optimists" whose motto is "Some day these things will change." Perhaps we will get enough members to authorize a change of custom, and the steel mill electrical fraternity will actually start to advertise their accomplishments; perhaps even get bold and push themselves into the "inner operating ring." When we do this, the electrical inspectors will become the "Electrical Mechanics," and the management will give them the "mantle" of acknowledged responsibility which we believe they should wear.

INSPECTION TRIP TO PITTSBURGH STEEL PRODUCTS CO.

Through the courtesy of President Homer D. Williams of the Pittsburgh Steel Co., members of the Association will have an opportunity to inspect the new Pilger Mill of the Pittsburgh Steel Products at Allenport during the latter part of October.

This is the first time any group of engineers have been invited to visit a mill making tubes by the German process. The equipment should be of particular interest to our members because all the motors and control, as well as the mill proper is of German manufacture, and it will be possible to compare foreign practices in steel mill electrification in a way that is not available at any other plant in the United States. The Mill at Allenport is completely electrically driven, and requires about 10,000 HP to drive the 152 motors installed.

Many of the steel mill engineers know that the tubes are made by the Pilger process by first piercing in a mill of the roller type, and then being rolled over a mandrel in the Pilger Mill, which is equipped with eccentric rolls. The process is practically one of forging tubes in a rolling mill.

We believe that this inspection trip to the Pilger Mill will provide valuable additions to the information of both the mechanical and electrical members of the Association.

Formal announcement of the detailed arrangements will reach you shortly.

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Power Factor Correction, Effective Power and Reactive Power*

W. H. FELDMANN†

A discussion of power-factor in terms of magnetizing current or reactive kv-a seems to offer a double advantage. First, it avoids analysis of phase relationship, with attendant confusion, when discussing the subject with non-electrical engineers. Second, it enables power-factor problems to be solved with simple arithmetic.

Many plant electrical engineers have experienced the difficulty of attempting to explain power-factor to the man who passes on appropriations. This man may be the chief engineer with mechanical training or an executive without the benefit of any engineering experience. Mechanical analogies have been the popular means employed. Analogies including the glass of beer, a ladder inclined against a building and a pump handling frothy liquid have all been used with varying success. Possibly a discussion of power factor in terms of magnetizing current may help some not reached by other simplified explanations.

The operation of every type of electric motor depends upon the reaction of one magnetic field upon another. One field is set up by the power or load current and the other by the exciting or magnetizing current. The necessary presence of this magnetizing current is responsible for low power-factor in alternating-current circuits. Magnetism has a property very similar to the mechanical inertia of a flywheel. The flywheel requires power to bring it up to speed but no power to keep its speed constant, except that necessary to overcome friction and windage.

The action is also similar to what takes place when a storage battery is floated on the line. When the line voltage is higher than the battery voltage, power is fed into the battery. This flow is reversed and power is given up by the battery, however, when the line voltage falls below the battery voltage. Let this charging and discharging continue regularly throughout a month, and suppose that a watt-hour meter, between the feeder and the battery, registers the energy transferred through the battery circuit. The watt-hour meter would register zero if the battery were 100 per cent efficient. Actually, it will register the battery losses.

The similar action of an alternating magnetic field can be demonstrated by a direct-current magnet. When potential is applied to such a coil, the current rises taking power but when the potential is removed, the magnet discharges a current giving up power. This magnetizing and demagnetizing of the coil, when completed, consumes no power for that purpose. Power is required only to overcome the losses of the coil. Except for frequency of reversals, this is exactly what happens when an alternating current is used for magnetizing. In the case of a 60-cycle circuit the current reverses 120 times a second and a large magnetizing current flows which takes no power. Hence, this current times voltage is the wattless power of a single-phase circuit. This is also referred to as the reactive kv-a.

The amount of this magnetizing current that is circulating around the system, in proportion to the power current, determines the power-factor. Power-factor is not a direct ratio of these two currents but varies as shown in the attached Table I. Therefore, an increase in the power current or decrease in the magnetizing current will improve the power-factor.

"As a basis for every alternating magnetic field, there must exist somewhere in the connected power system a direct magnetic field (excited by direct current.) This might be termed the basic magnetic field, since it is the foundation of all the alternating fields, in magnets, transformers, induction motors, etc. It may exist in the generator only, or it may be supplied at various places in a system." #

TABLE I

Power Factor	Ratio of Reactive Kv-a to Kw.	Power Factor	Ratio of Reactive Kv-a to Kw.
1.00	0.0000	.74	0.9089
.99	0.1425	.73	0.9362
.98	0.2030	.72	0.9639
.97	0.2506	.71	0.9918
.96	0.2917	.70	1.0202
.95	0.3287	.69	1.0490
.94	0.3630	.68	1.0782
.93	0.3952	.67	1.1080
.92	0.4260	.66	1.1383
.91	0.4556	.65	1.1692
.90	0.4843	.64	1,2006
.89	0.5123	.63	1.2327
.88	0.5398	.62	1,2655
.87	0.5667	.61	1.2990
.86	0.5934	.60	1.3333
.85	0.6198	.59	1.3685
.84	0.6459	.58	1.4045
.83	0.6720	.57	1.4415
.82	0.6980	.56	1.4795
.81	0.7238	.55	1.5185
.80	0.7500	.54	1.5587
.79	0.7761	.53	1.6000
.78	0.8023	.52	1.6427
.77	0.8284	.51	1.6866
.76	0.8552	.50	1.7321
.75	0.8819		

If we assume that the only direct magnetic field is in the generators, then it is necessary to transfer the energy from this field through the entire electrical transmission circuit to build up the magnetism of an induction motor, for example, and transfer the energy back in the last half of each alternation. Hence, the magnetizing current simply transmits energy from the basic field in the generator back and forth and it takes no power, or is wattless, as its net transfer in either direction is zero.

As stated before, power-factor is increased as the alternating magnetizing current is decreased. Obvi-

*Presented before Pittsburgh Section, March 19, 1927.

†Engineer, Electric Machinery Mfg. Co., Minneapolis, Minn.

From The Power-Factor Book, published by the Electric Machinery Mfg. Company, Minneapolis, Minn.

ously, this is accomplished if the need for alternating magnetism is reduced or if basic magnetic fields are supplied to the system near the alternating magnetic fields. This is often done by synchronous motors and similar devices. The circuit between the basic field and the alternating field can be relieved of the magnetizing current by means of a static condenser. This is due to an interchange of energy between the alternating magnetic field and the dielectric field of the condenser.

DETERMINATION OF SAVINGS

Poor power-factor, due to circulating excessive magnetizing current through the system, results in a number of disadvantages which may be summarized as follows:

1. Poor voltage regulation, resulting in decrease in quality and quantity of manufactured products.
2. Higher energy losses.
3. Higher investment in electrical equipment.

Where Power Is Purchased

In considering savings resulting from improved power factor, it is necessary to determine if power is purchased or generated, and if purchased, the nature of the rate of the Utility Company with respect to power-factor. Mr. Sykes, Consulting Engineer of the Inland Steel Company, Chicago, stated in a recent address before the Midwest Power Conference, that 25 per cent of the power used in the steel industry is purchased from central station companies. Purchased power entering to this extent into the operation of the steel industry is, therefore, of sufficient importance to justify consideration here.

When a power user improves power-factor, the central station saves at the coal pile because of decreased generator, transformer and transmission line losses resulting from circulating less magnetizing current and also in fixed costs due to lower investment principally in the electrical side of their system.

There are two general methods employed in rate schedules in penalizing for low power-factor. First, rate adjustment based on average power-factor; second, rate adjustment based on power-factor at the time of maximum demand. It would seem that a central station basing rate adjustments on average power-factor, would have the benefit of saving in energy losses foremost in mind, although, of course, power factor corrective equipment that improves average power-factor will to some extent improve peak power-factor. Also it would seem that the power company basing rate adjustment on peak power-factor would have the benefit of lower system investment foremost in mind; although, of course, the means for obtaining high peak power-factor would probably result in a substantial increase in average power factor. The reason, however, for the adoption of one or the other method of adjusting rates for power-factor has been up to the present time largely determined by metering problems. A reactive kv-a-h meter, which totalizes the magnetizing current over a given period and enables the determination of average power-factor, is a good bit less costly and cheaper to maintain than a recording kv-a or power-factor meter, necessary for the determination of peak power factor. It is not important here to discuss the justification of each particular case, but to point out that they exist. They naturally affect seriously the solution of a particular power-factor problem.

When average power-factor is used, as is the case with the Duquesne Light Company rates, it is usually the practice to ratchet the kv-a-h meter so that a leading power-factor condition is not averaged in with a lagging-factor condition at a different time. This, therefore, suggests that the form of power-factor corrective equipment be chosen so that it will operate a substantial part of the time as every leading reactive kv-a-h that is put into the system at any time will pull up the average power-factor, provided the plant power-factor at that time is not leading. Thus, a static condenser, so chosen that it will operate for the purpose of improving average power-factor, at its full capacity during the 24 hrs. of the day, will have considerable merit as a means of improving average power-factor. One suggested method to determine the largest static condenser that can be used and provide its full rating for the purpose of improving average power factor 24 hrs. a day, is to install printometer tape mechanism on the reactive kv-a-h meter. This reveals the curve of the wattless power from half hour to half hour. If a condenser is chosen so that its leading reactive kv-a just equals the minimum lagging reactive kv-a of the plant, the maximum output of the condenser is continually useful for power-factor correction. Of course, it may work out that a static condenser would be a good investment even when operating something substantially less than 24 hrs. per day at 100 per cent of its rated capacity.

The plan of adjusting power rates on the basis of power-factor at the time of maximum demand is being more widely adopted. This is the well known kv-a demand basis of billing and is often employed in special contracts for exceptionally large blocks of power. Obviously, from the standpoint of possible saving in power rate alone, the larger apparatus, that is always in service at the time of maximum demand, should be driven with unity of leading power-factor electrical equipment.

The reduction in power bills can be accurately anticipated. All that is required is a knowledge of the power rate schedule and some test data. Of course, if corrective equipment is installed near the point where the alternating magnetizing current is required, there will be an additional saving in distribution losses in the power user's plant and an improvement in voltage regulation. The last two benefits, while real, do not impress the plant owner or manager as does the more evident saving in monthly power bill. Fortunately, the lower power rate, alone, often justifies the necessary investment in corrective equipment.

Where Power Is Generated

When a plant is generating its own power, the engineer can determine the relation between fuel cost and fixed charges and thus stress high average or high peak power-factor improvement.

Mr. Sykes, in the paper previously referred to, made the statement that usually power can be purchased to advantage where no blast furnaces are in operation. Or, expressing it another way, power can usually be generated to advantage where blast furnaces are installed. Therefore, benefits resulting from power-factor improvement where power is gen-

erated are of particular importance to the engineers of the larger steel mills.

In general, if the central-station companies, with a supposed intimate knowledge of power generation and distribution costs, offer a lower power rate for higher power-factor, the private plant operator likewise realizes a substantial saving. Rate savings resulting from power-factor improvement vary widely. In many instances, of which the Duquesne Light Company's rate is an example, it amounts to from 6 to 8 per cent of the total bill, for a rise of power-factor from .70 to .95.

If a large steel plant has a distribution problem comparable to that of a central station, and if we assume that the power-factor rate of the central station is justified; then in general a saving in total power cost of about 6 per cent, by increasing power-factor from .70 to .95, is realized. If we are not inclined to accept such a general statement, we can analyze the effect of power-factor on factors making up the cost of delivered power generated on the premises.

Poor power-factor, or the circulating of excessive magnetizing current, results in an increase in the copper losses of I^2R losses. This occurs in generators, transformers and feeders.

In generators there is the additional armature current resulting from wattless current in the line and also the additional field current that is required to offset the effect of the wattless current on generator voltage. Armature copper loss in a medium sized turbo alternator is about 0.5 per cent and field-copper loss 0.2 per cent with a unity power-factor load. Full-load armature copper loss varies as the reciprocal of the square of the power-factor, and field copper loss is affected by the power-factor in various ratios, depending upon the alternator design. Thus, armature copper loss will be increased to approximately 0.56 per cent at .95 p.f. and 1.0 per cent at .70 p.f. Field copper loss will increase approximately to 0.3 per cent at .95 p. f. and 0.6 per cent at .70 p.f. The effect on stray load losses is slight and can safely be ignored. If a direct-connected exciter is used, the rheostat losses will be practically unaffected; exciter losses will be somewhat increased.

In considering the increase in copper losses in transformers, let us assume a 1000 kv-a, 2300/13,200-volt bank carrying 700 kw. load. The copper loss would increase from .869 per cent at unity power-factor to .931 per cent at .95 power-factor and 1.714 per cent at .70 power-factor.

Transmission line and feeder losses, or distribution losses, may be almost anything; but may be assumed to be about 5 per cent at unity power-factor in a good average layout. This becomes 5.54 per cent at .95 power-factor and 10.02 per cent at .70 power-factor.

Thus the relation between total copper loss at unity power-factor and at .70 power-factor, on the basis of the above assumption, is .993 x .99131 x .95 = .934 (which is 6.6 per cent) for unity power-factor; and .984 x .98286 x .8998 = .869 (which is 13.1 per cent) for .70 power-factor. The figure for .95 power-factor is 7.2 per cent.

Investment and fixed costs are affected somewhat as follows by power-factor. The cost of electrical equipment for a given kw. load usually varies approximately as the kv-a capacity, so that the fixed charges vary approximately inversely as the power-factor.

Except for the increase due to copper loss, as pointed out above, the major part of power plant and system investment does not vary much with the power factor. This includes buildings, boilers, turbines, condensers, most auxiliaries, tower or pole lines and insulators. Generators, exciters, transformers, switches and feeders vary in cost approximately inversely as the power factor. The investment in the latter or electrical side runs from $10 per kv-a up; and $15 may be considered an average value. # Considering interest at 6 per cent, depreciation 6 per cent, insurance and taxes at 3 per cent, annual fixed charges will be 15 per cent of $15 or $2.25 per year per kv-a. Assuming 50 per cent annual load-factor, fixed costs per kw-h. are .515 mill at unity power factor, .543 at .95 power-factor and .736 mill at .70 power-factor. Thus, if the power-factor is .70 instead of .95, fixed costs per kw-h. increase .193 mill or 35 per cent.

As previously pointed out, the energy loss in the electrical system is approximately 6 per cent greater at .70 power-factor than at .95 power-factor. There is also the possibility of decrease in efficiency in the steam side of the plant as with a .70 power-factor it is likely the steam equipment is being operated at less than full capacity. Let us assume the cost of power, at .95 power-factor, to be 10 mills delivered to the motor and made up as follows:

	Cost	
Fuel	5.8	mills
Labor	.91	
Water	.35	
Maintenance	1.1	
Miscellaneous	.04	
Fixed costs electric	.543	
Fixed costs others	1.257	
	10.000	

Fuel increases to 6.15 mills and electrical fixed costs to .736 mills at .70 power-factor, or a total increase in power costs of 5.43 per cent. This checks reasonably well with the discounts allowed by power companies when their greater problem of distribution is taken into consideration.

In actual practice, with an existing plant, a saving in fixed costs is not realized until it is necessary to increase distribution, transforming or generating equipment. Then power-factor improvement will show a good return by either postponing the need for more equipment or minimizing the investment.

Even if equipment is adequate for operation at low power-factor it may be necessary to operate an additional unit resulting in greater energy loss. With fuel cost per kw-h established, estimates of the saving in copper loss by improving power-factor can be readily determined as suggested above for a particular plant. Even though blast furnace gas is used for a large part of steam generation and is not charged to power production the fuel used to overcome copper losses will likely be coal for the most part as it makes up the last 5 to 10 per cent of the load.

See Cost and Prevention of Low Power Factor, Electrical World August 15, 1925, by Philip Chapin Jones.

MEANS FOR CORRECTING POWER FACTOR

Static Condenser

One advantage in thinking of a power-factor problem in terms of magnetizing current is that it enables one to use a very simple method of calculating results. In Table I the figures under the heading "Ratio of reactive Kv-A to Kw" are the tangents of the angles whose cosines are the power-factors in the first column. Thus, at .70 power-factor the magnetizing current is 102 per cent of the load current and at .95 power-factor, 32.9 per cent. If then, without increasing load, we desire to increase the power-factor from .70 to .95 we must eliminate a portion of the magnetizing current equal to 69.1 per cent of the load current. For example, a 1000-kw. load would have 1020 reactive kv-a at .70 power-factor and 329 reactive kv-a at .95 power-factor. The difference, of 691 reactive kv-a, must be eliminated, in one of several ways (the load remaining unchanged) if power-factor is to be raised from .70 to .95. The installation of a 691 kv-a static condenser is one way to accomplish the result.

This is a typical solution of a problem with a static condenser where peak or demand power-factor is the determining factor. The proper application of a static condenser to improve average power-factor where the reactive kv-a-h meter is ratcheted is more involved. An actual case may indicate one satisfactory method. A printometer installed on the reactive kv-a-h meter revealed the following variation in reactive kv-a:

Time A. M.	Average Week Day	Average Sunday
12		
1	205	180
2	210	170
3	210	165
4	205	195
5	215	185
6	220	210
7	250	200
8	350	220
9	550	240
10	600	265
11	620	230
P. M.		
12	585	245
1	590	260
2	635	230
3	670	250
4	610	210
5	685	240
6	665	215
7	420	190
8	355	195
9	270	210
10	250	145
11	205	175
12	215	165

Thus, six days a week, a 205-kv-a static condenser will contribute its full output 24 hours a day; or it will supply 205 x 24 = 4920 leading reactive kv-a-h a day. On Sunday, however there are 10 hours where the reactive kv-a is below 205 and the condenser will only supply 4535 leading reactive kv-a-h useful for improving average power-factor. It worked out in this particular case, however, that a 250 kv-a condenser, even though its output was useful but 95 per cent of the time week days, showed the highest return due to a peculiarity in the power rate schedule.

Synchronous Condensers

Steel mills with weekly load-factors of .60 to .65 will find static condensers to be preferred over synchronous condensers except in very large sizes, where the power system is 60 cycles. The use of static condensers on 25-cycle circuits is less advantageous, as the kv-a capacity, for a given area of condenser surface, varies directly as the frequency. To illustrate, let us assume a 1300-kw. load at .70 power-factor, with the desire to raise the power-factor to .95. The reactive kv-a to be eliminated is (referring to Table I) (102-32.9) x 1300, or 69.1 x 1300 = 900. A synchronous condenser of this size will only cost about $6,300 installed, against $17,000 for static condensers. However, the losses of the synchronous condenser will be 40 kw. as against only 2.25 kw. for the static condenser. That difference of 37.75 kw. x 8760 hours x 1 cent = $3,300 a year. This, capitalized at 15 per cent or even 20 per cent increases the economic cost of the synchronous condenser to $22,800 as against $17,000 for the static condenser.

Ease of adjustment of reactive kv-a with a synchronous condenser is of little advantage because the power loss, in static condensers, of only ¼ of 1 per cent, makes it inexpensive to leave them in circuit even though the plant is only operating at half capacity. Of course, the static condenser has a big advantage in the matter of maintenance.

Either type of condenser can, of course, be installed with no interference to production.

Synchronous Motors

The advantage of using synchronous motors for power-factor improvement in the above case will be evident by using actual figures of a power factor correction problem solved by this means. Several 300 h.p. motors were required for an application heretofore considered an induction motor drive. Here is how the two types of motors compared from a power-factor standpoint:

Motor	Load	Power Factor	Eff. per cent	Kw. Input	Kv-A Input	React,Kv-A Input	Sum
Induc.		.88 lag.	92.0	243.	276.	131. lag.	
Sun.	4/4	.80 lead	92.9	241.	301.	181. lead	312.
Induc.		.86 lag.	91.5	183.5	213.5	109. lag.	
Syn.	3/4	.65 lead	91.0	185.	284.	216. lead	325
Induc.		.80 lag.	88.5	126.5	158.	95. lag.	
Syn.	1/2	.49 lead	87.5	128.	260.	227. lead	322

As the average load was between 50 per cent and 75 per cent, it is very conservative to consider the synchronous motor as equivalent to the induction motor plus a 300-kv-a static condenser. Three of these motors operating continuously would meet the requirements of the previously assumed problem. The difference in cost of the two types of motors was only $2,000 each so the cost of corrective equipment, in the form of synchronous motors, would be $6,000 or $6.66 per reactive kv-a against $7 for a synchronous condenser and $18 for a static condenser. The difference between kw. input at 1/2 or 3/4 load or 1.5 kw. represents the power loss chargeable to correction. In this instance it is less than .5 kw. per 100 reactive kv-a. Even if these motors only operated 50 per cent of the time against full

time operation for pure corrective equipment, their use enables the most economical correction.

In this case very high starting, pull-in, and pull-out torques were guaranteed, giving promise of successful service.

There are a number of reasons why a leading power-factor synchronous motor is so often the most economical means of improving power-factor:

1. When used for the double function of delivering mechanical power and supplying correction its materials are used most effectively for these reasons: Power is transmitted by the energy component of the current while correction is effected by the wattless component. The geometric resultant, or sum, considering phase relation, determines heating and is less than the algebraic sum, of power delivered to the load and reactive power delivered for correction purposes. This can be made clear by a simple triangle of components representing an .80 power-factor synchronous motor.

The measure of the total result obtained for the two purposes, is the sum of OA and AB or 140. The heating of the machine is determined, however, by OB or 100.

Where the investment for power-factor correction purposes is represented by the difference between induction motor investment and synchronous motor investment, as in new installations, it approaches synchronous condenser investment. It is usually well below static condenser investment even when very nearly the total investment is charged to correction as is the case when replacing existing induction motors.

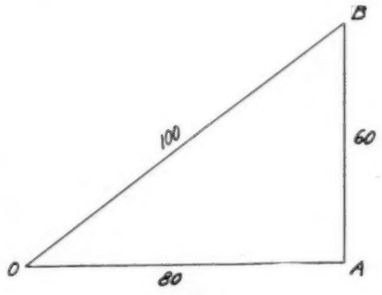

FIG. 1.

2. In general, the addition of a new power-factor corrective electrical load, of a stated number of kv-a, will produce its maximum corrective effect when its reactive-factor is chosen equal to the expected resultant power-factor of the system. This can be proven with reference to Fig. 2. To quote from The Power-Factor Book, previously cited:

"Consider an initial load OA of 1200 kv-a and power-factor .20. It is to be improved as much as possible by adding 200 kv-a. Evidently the maximum improvement must occur when the 200 kv-a is added in the direction AC, at right angles to OC; its addition in any other direction, such as AF, would not produce so small an angle Θ. The angle Θ becomes minimum when OC is tangent to the arc BCF (drawn with radius AF = 200 kv-a). And, when OC is tangent, the angle ACO is a right angle. Since the triangle ABC (representing the added load) has its three sides respectively perpendicular to the three sides of the triangle OHC (representing the final resultant load) it is apparent that these two triangles are similar. Angle a of the small triangle is equal to angle Θ of the large one. Hence, cos Θ = cos a = sin B. But cos Θ is the power-factor of the system after improvement, and sin B is the reactive-factor of the added load."

"This relation holds true for any possible power-factor of the resultant system, such as that represented by the angle GOX or the angle KOX. If the initial system is represented by OR, the maximum improvement occurs when the added load, RG, is perpendicular to OG. Again, if the initial system is represented by OS, the maximum improvement is assured by making SK perpendicular to OK. In all of these cases the triangle of the added load is assumed to have a constant hypotenuse and hence represents the same apparent power (AC = RG = SK)".

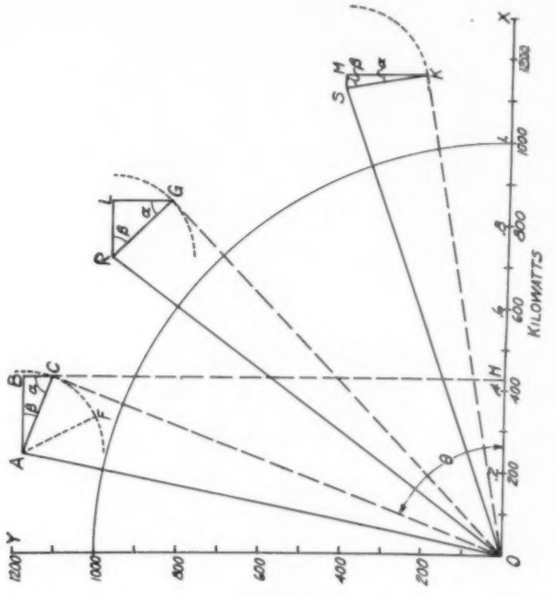

FIG. 2.

Expressing this differently, we can say that the maximum corrective effect is added when the power-factor of the corrective equipment has a relation to the expected resultant power-factor of the system, as shown by the following table:

Resultant Power-Factor	Power-Factor of Corrective Equipment (Leading)
.50	.86
.60	.80
.70	.71
.80	.60
.90	.44
1.00	0

Thus where power-factor is improved to the usual values of .80 to .90 a partially loaded synchronous motor, affords more correction for a given kv-a rating than pure condenser equipment.

3. High speed .80 leading-power-factor synchronous motors may be as much as 1 per cent lower in efficiency than induction motors of equal rating. Medium or low speed .80 leading-power-factor synchronous motors however have equal or higher efficiencies than corresponding induction motors. Where the efficiency is equal, obviously no additional power is used to furnish the leading reactive kv-a to the

system, which in the case of an .80 power-factor motor is 75 per cent of the kw. input.

4. A leading-power-factor synchronous motor not only supplies correction in the form of leading reactive kv-a but its use avoids the operation of an induction motor with its demand for alternating magnetizing current or lagging reactive kv-a. This is true in varying degree at all loads as shown by the reactive kv-a figures in the tabulation of power factor characteristics given above for 300 h.p. motors. Power-factor characteristics of synchronous motors at part loads are shown by the curves of Fig. 3.

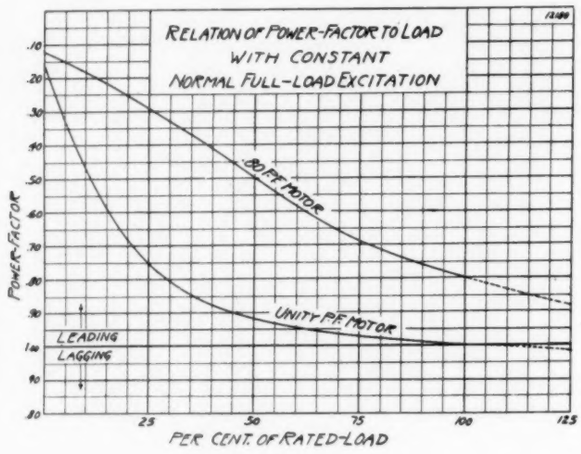

FIG. 3.

Where sufficient power-factor improvement cannot be obtained by the well established synchronous motor drives such as M-G sets, compressors, blowers, and pumps, there are many steel mill applications that can be successfully operated with modern high torque synchronous motors. Starting torque of 200 per cent, pull-in torque of 150 per cent and pull-out torque of 300 per cent are available with medium-speed leading-power-factor synchronous motors, and these values can be increased by overmotoring. The attendant high starting current will in most cases be so much less than other peaks as to constitute no objection.

If an application meets the following requirements it may offer opportunity for power-factor improvement by the use of leading-power-factor synchronous motors:

1. Constant speed.
2. Non-reversing.
3. Length of pass over 5 seconds.
4. Reasonable ratio of friction to normal load.

DISCUSSION

A. F. Kenyon*: I am sure that we all appreciate the very fine paper that Mr. Feldmann has presented. His method of calculating power factor correction problems is a simplification of usual methods, and undoubtedly makes easier the discussion of the problem with executives of the company who do not have technical training.

I might mention at this time that there has been a change in practice which affects the power factor situation in many plants. When electrical drives were first being applied to rolling mills, it was quite common practice to install slow speed direct connected induction motors, and you are familiar with the low power factor of such machines. The improvements that have been made in herringbone gear units have permitted the use of higher speed induction motors which have comparatively high power factor, and hence the more recently built plants, even though the main drives are of the induction type, do not have the low power factor conditions so frequently found in the older plants.

Another thing which Mr. Feldmann may have overlooked is the rapidly increasing use of direct current motors on rolling mills. In looking over the list of installations made by one large manufacturer during the past year, I find that approximately 75%, both in point of number of units and of rated capacity, of the main roll drives now being sold are of the direct current type, and in the majority of cases they are supplied with power from synchronous motor generator sets. In a great many plants, synchronous motor generator sets offer a very good opportunity for securing power factor correction. We find, too, with this increasing use of direct current drives, that some plants are becoming "over-power factored." This is reflected in some recent specifications calling for unity power factor machines, whereas a few years ago 80% was nearly standard.

A. B. Emerick*: It happens I am just starting my seventh week in Pittsburgh territory and also my first experience in connection with steel mills. Am very glad to get the information I did here this evening, because the steel mill has been out of my game. My experience has been with smaller types of drives where one or two replacements in a plant, possibly five or six at most, increases your power factor from 85 to 90 per cent, and that is entirely different from steel mill practice.

Lee H. Mandeville†: We can run our power factor at the present time to 90 per cent leading if we want to. We have operating 12,000 k.w. Induction motor load is made up of one 4,000 and one 5,000 and the balance is made up of from 250 h.p. down. I think this is the first plant under my supervision which has as high a power factor as is needed.

L. J. Lamberger‡: I have enjoyed Mr. Feldmann's paper very much because of the simplified form in which it was given and I think it has enlightened all of us quite a bit. The Duquesne Light Company quite some time ago realized the importance of keeping up the power factor on its system. I believe all central stations do now, and many have inserted into their power rates a clause whereby the power user gains the benefit of a discount where the power factor is kept above a certain point. In the Duquesne Light Co. rates this point is 75 per cent, that is the allowable power factor is 75 per cent. Below 75 per cent, penalty is added; above that, discount is allowed.

Mr. Feldmann brought out that steel mills, which are operating central generating plants, are affected the same way as the central stations, and no doubt

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with them maintaining a high power factor is just as important as it is to central stations. The discount allowed by central stations, therefore, will no doubt serve as a criterion to be followed in figuring their advantages in keeping up power factor.

H. A. Waddell*: I do not know as I have anything to add. I have one customer in my district who has rather poor power factor and that is quite an item. Mr. Stark is the Electrician of that mill and very much interested in that feature of the thing from the fact that they wish to reduce their cost. In the territory I have charge of, the power factor is good from the fact that we have mostly mine installations with synchronous M. G. sets, which correct power factor for that neighborhood. The Apollo Steel Company is the only one in that territory with low power factor, and I am sure Mr. Stark is particularly interested in this subject.

H. O. Swoboda†: I have made a great many power factor investigations and found that a number of plants continue to operate with a low power factor in spite of the complaints which have been made to them by the Duquesne Light Co. The reason is, that the Duquesne Light Co. is very lenient and does not penalize for a low power factor. I know, for instance one plant which operates with a power factor of from 80 to 90 per cent at full load. At times, however, when half of the plant is shut down and with it a large synchronous motor, the power factor of the other portion of the plant drops to as low as 40 per cent. When mentioning this matter to the parties in charge of the plant, they merely replied that so long as they are not penalized, they would not be willing to spend any money to improve the power factor. Similar cases can be found in this territory quite often. As stated before, it is my opinion that the Duquesne Light Co. is altogether too lenient.

W. P. Stark‡: I came down here primarily to get some information. We are running with a power factor of 70 to 80 per cent. We are figuring on an installation to bring the power factor up and save some money.

O. A. Memeke§: We have synchronous motors installed to take care of power factor.

R. F. Chaffin**: I think Mr. Feldmann made a statement that is not quite correct when he said the common practice in a steel plant is to figure waste gases or waste fuels at a relatively low cost. I think it is common practice to figure those waste fuels on B.t.u basis and charge the coal equivalent. Even figuring it out that way you can in a fairly modern plant successfully compete with a central station in the generation of power for your mill. I do not think Mr. Feldmann gave you just the proper slant on that.

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†Consulting Engineer, Pittsburgh, Pa.
‡Elec. Engr., Apollo Steel Co., Apollo, Pa.
§Standard Seamless Tube Co., Ambridge, Pa.
**Elec. Supt., Pittsburgh Crucible Steel Co., Midland, Pa.

Mr. Fisher: A certain power user maintains, by the use of synchronous motor generator sets, unity or leading power factor. He is the only customer on that line and he gets a 5 or 6 per cent discount for maintaining unity power factor. He claims the power company derives more benefit from his good power factor than he does. Is that correct?

Mr. Feldmann: Answering Mr. Fisher, it depends entirely on the line or feeder conditions between the power company's generating station and the customer's load. You will recall, in the analysis of the cost of poor power factor in the paper, that a large part of the cost was line loss or I^2R loss. Hence, what the power company saves, depends largely upon the line conditions applying to a particular customer. Some power companies give more than 6% discount for unity power factor and some less. But whatever it is the amount they profit by their customers raising power factor to unity varies with the local conditions.

Mr. Fink: We are figuring on a synchronous motor proposition at the present time. Our problem is to bring the motors up to speed gradually. Can Mr. Feldmann give us any idea of how to avoid too quick starting?

Mr. Feldmann: Speed of acceleration is determined by the amount the torque of the motor exceeds the torque required to move the driven load. Recently a customer came to us for a 1200 R.P.M. motor to be belted to an air compressor and arranged for full voltage or across-the-line starting. A standard motor, started in this manner, would develop approximately 150% starting torque which would have been so much in excess of the requirement of the compressor that no doubt the belt would have come off. By a special design the motor was provided with about 40% starting torque, acceleration was relatively slow and the requirements of that job successfully met.

L. J. Lamberger: The maximum discount we allow, for unity power factor, is 8.819 per cent on the gross bill, that is, before the prompt payment discount is taken out.

In answer to Mr. Swoboda's remarks about not penalizing, I would like to say that this power factor clause was incorporated into the rates a few years ago, and it would hardly be fair to our customers to put the penalty into effect before they had had a reasonable amount of time to correct for poor power factor conditions. I think as time goes along and customers on Duquesne Light Company's lines will have had ample time to correct for power factor less than 75 per cent, it may be that the Duquesne Light Company will some day put the penalty into effect. The reason they haven't done this before is to give customers time enough to make provision to correct low power factor conditions.

Inductive Time Limit Control

By N. L. MORTENSEN*

THE "IRON AND STEEL ENGINEER" has recently published several articles discussing the relative merits of current and time limit control, as well as some of the characteristics of different types of control. While current limit control has been used principally in the past, during the last few years the time limit principle of acceleration has come more and more into prominence for control equipment used in connection with D. C. motors operating auxiliary mill drives.

It seems to be fairly well recognized that while with current limit control, it is possible to adjust the controller so that the motor will not take more than a cerain amount of current, it is only in the case of heavy inertia load, or where there is little variation in load, that this type of control gives the best starting condition. Where the load is partly or mostly friction load, and varies, like that encountered in connection with auxiliary steel mill drives, it is necessary to adjust the controller for the heaviest load, in order to insure starting under all conditions. Consequently, the motor and control equipment must handle and commutate the maximum current, and the machines are always subject to stresses imposed by these currents, regardless of the load on the mill, and the time of acceleration varies with the load. Also, if ever the load is in excess of that for which the relays are set, the motor will stall. The maximum load generally occurs when the mill is cold; after the mill has been in operation for some time, the load soon decreases.

With time limit control, the whole equipment can be adjusted for the normal load condition. In case of heavier load, the accelerating current will increase, but the motor will still be accelerated. However, the maximum load condition is obtained only a relatively small percentage of the time. Experience in motor application has made it possible to choose motors that will satisfactorily operate the mill under all conditions met during normal operation, and it is only in an emergency condition that any protection is required. This protection is obtained with a time limit controller. In the case of a stalled motor, the controller will proceed to function, cutting out the resistance, until the current has reached such a point that the overload protective devices disconnect the motor. Furthermore, time limit control makes the motor respond more directly to the master handle, and there is not the variation in acceleration that is obtained with current limit control when the load varies.

The time limit method of acceleration is not by any means new. It has been used about as long as automatic control has been built. Different means have been used to obtain the time delay, such as dashpots, pilot motors, clock mechanisms, etc. Such controllers have, in general, not proved satisfactory for steel mill applications, because the timing means have not been reliable under the severe operating conditions encountered. Controllers have also been built utilizing the time of closing of the contactors themselves, the necessary time being obtained by using sufficient contactors to give the required time for acceleration. This control is not flexible enough to meet different service conditions, and each control will practically have to be modified for the particular installation.

Recent development has placed on the market, time limit controllers where the timing is obtained by the inductive principle, and it is the purpose of this paper to outline some of the theories and principles of operation of a type of controller utilizing a transformer to obtain the time element.

The law of induction, as given by Faraday, tells us that when the magnetic flux within a loop of wire varies with the time, an E.M.F. is induced in the loop, the instantaneous value of which is proportional to the rate of change of flux. This is expressed by the equation:

$$e = \frac{d\,\phi}{dt}$$

Further, any electric circuit containing magnetic or electrostatic fields, represents stored energy. If, therefore, a constant direct current voltage is impressed on such a circuit, the current does not instantly reach its permanent value, and a definite time must elapse, during which time energy is stored in the circuit. While the conditions of the circuits are changing, a transient phenomenon occurs, until the stored energy has been re-adjusted. In this case, as in practically all low voltage circuits, the electrostatic energy is negligible, and only the inductance need to be considered. The shunt field of a direct current motor is a good example of this phenomenon. When the motor field is disconnected from the line, a voltage is induced, and unless discharge resistance is connected across the field to absorb energy, it may result in breakdown of the insulation.

Considering now an electric circuit containing a resistance, r, and an inductance, L, as represented by Fig. 1. On this circuit, a direct current voltage e_0 is impressed. If the voltage suddenly is withdrawn and the circuit is short circuited, the voltage and current do not instantly drop to zero, but decrease in accordance with the following equation:

$$e = e_0\ E\ -\ \frac{r}{L}t$$

$$i = i_0\ E\ -\ \frac{r}{L}t$$

where e_0 and i_0 are the voltage and current before the change took place, e and i the induced voltage and current, E the base of the natural logarithms, and t the time interval from the moment the change takes place.

The time required for the current to decrease to a certain value is then:

$$t = \frac{L}{r}\ \mathrm{Log}\ \frac{i_0}{i}$$

It can be readily seen from the equations, that the time required for the current to decrease from the value i_0 to a certain value i, will increase with

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an increase in the value of the inductance L, and also with the decrease in value of the resistance r.

Similarly, if a voltage e_0 is suddenly impressed on a circuit, the current does not immediately reach the permanent value, but rises in accordance with the following equation:

$$i = i_0 \left(1 - E - \frac{r}{L}t\right)$$

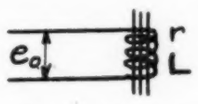

Fig. 1

The voltage during the change is consumed partly by the resistance and partly by the inductance as follows:

$$e_0 = ir + e_0\, E - \frac{r}{L}t$$

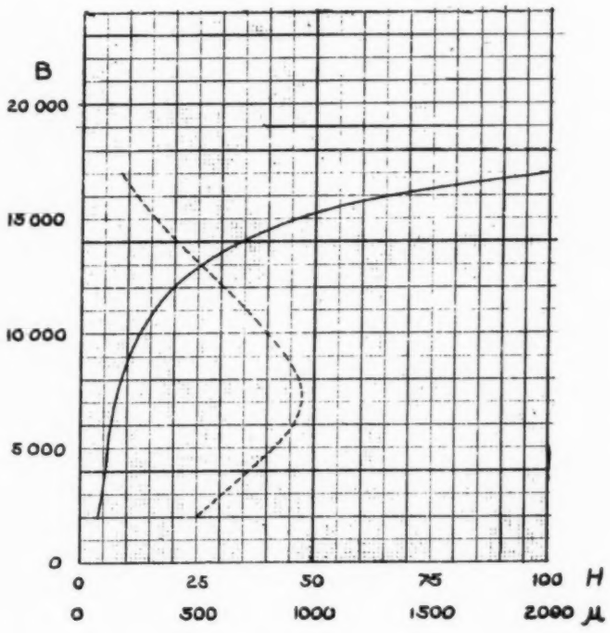

FIG. 2.

The inductance L is dependent upon the number of interlinkages with the flux produced by the unit current in the circuit as follows:

$$L = \frac{n\,\phi}{i}\,10^{-8}$$

Where L and r are constant, the decrease or rise of the current is a simple exponential curve. In a circuit containing iron, the inductance L is not constant, but depends upon the permeability. For a closed iron circuit, the value L is as follows:

$$L = 4\,\pi\,n^2\,\mu\,\frac{A}{l}\,10^{-9}$$

where μ is the permeability, A the area of the magnetic circuit, l the length of the magnetic circuit, and n the number of turns. The value μ varies with the saturation, and Fig. 2 shows a permeability curve. The transient current in a circuit containing iron, therefore, changes relatively fast on higher current where the iron is saturated and μ small and relatively slow on lower magnetic densities.

Fig. 3 is an oscillograph curve showing the decrease and rise of current for a circuit, as shown in Fig. 1. Curve No. 1 shows the decrease in current when the circuit is short-circuited, and curve No. 2, the increase in current when the voltage is suddenly impressed on the circuit.

When two or more circuits are so located that part of the magnetic flux is interlinked with both or all of the circuits, the induced voltage or current in any one of the circuits are no longer determined by the impressed voltage of that circuit only, but are also dependent upon the conditions of the other circuit and relation between them. The circuits contain what is termed "mutual inductance."

An example of such a circuit is the field of a compound wound motor. In starting such a motor,

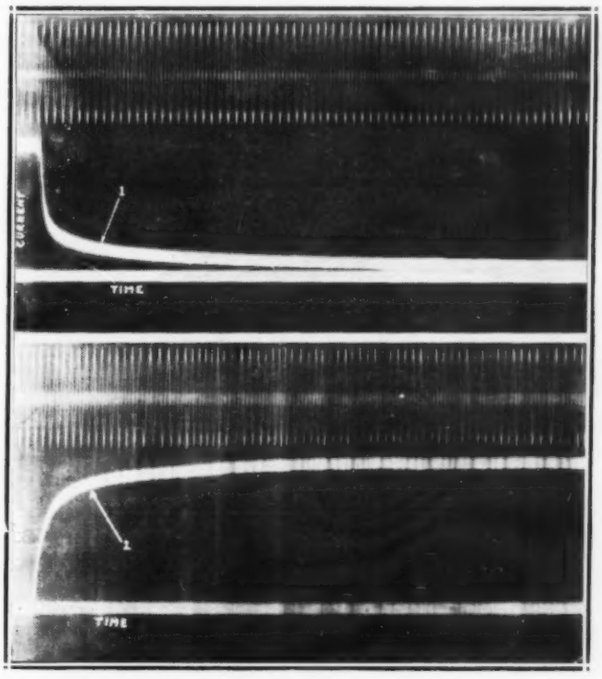

FIG. 3.

having a very heavy series field, the shunt field current will be reduced considerably and sometimes reversed, when the motor is started.

Such a circuit, having two coils, is represented by Fig. 4; one coil having the resistance R_1 and inductance L_1, and the other having the resistance R_2 and inductance L_2, and a mutual inductance M, which is dependent upon the inter-linkage of flux between the circuits.

If a voltage e_1 is suddenly impressed on the one circuit and e_2 on the other circuit, the equations for the circuit are as follows:

$$e_1 = i_1 r_1 + L_1 \frac{di_1}{dt} + M \frac{di_2}{dt}$$

$$e_2 = i_2 r_2 + L_2 \frac{di_2}{dt} \quad M \frac{di_1}{dt}$$

where i_1 and i_2 are the induced currents in the circuit.

The induced currents are expressed by the following equations:

$$i_1 = \frac{e_1}{r_1} + A_1 E^{-m_1 t} + A_2 E^{-m_2 t}$$

$$i_2 = \frac{e_2}{r_2} + B_1 E^{-m_1 t} + B_2 E^{-m_2 t}$$

where m_1 and m_2 are factors similar to $\frac{r}{L}$ in the equation where only a single circuit was considered, but in this case, the values m_1 and m_2 are determined by

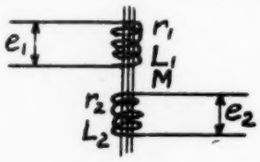

FIG. 4.

the resistance and the inductance of both of the circuits, as well as by the mutual inductance. If there is iron contained in the circuit, the inductance is not constant, but varies with the permeability μ, as previously explained.

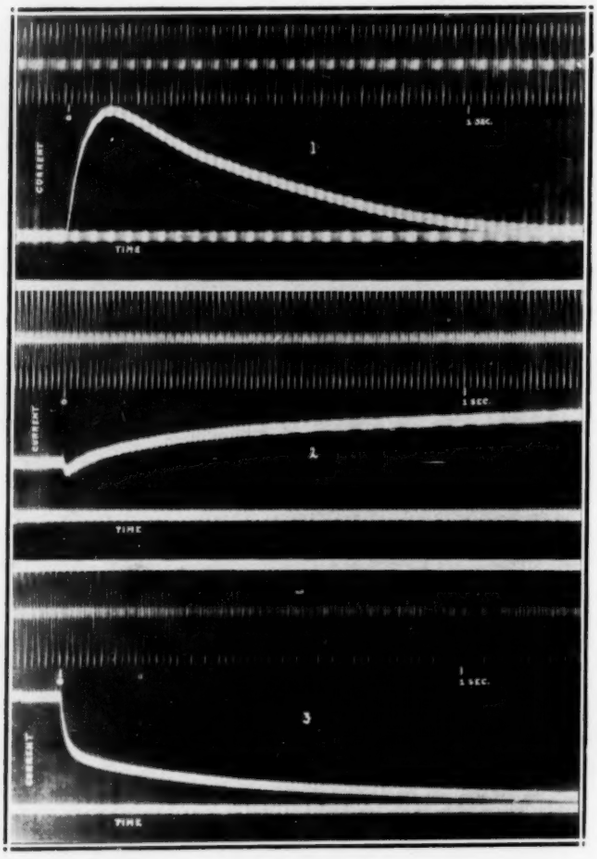

FIG. 5.

A_1 and A_2, as well as B_1 and B_2, are determined by the electrical condition of the circuit before and after the change has taken place.

If the coils are used as primary and secondary, and the primary has voltage impressed on it, and the secondary is short-circuited, $\frac{e_2}{r_2} = O$, the equation for the current in the secondary is then:

$$i_2 = B_1 E^{-m_1 t} + B_2 E^{-m_2 t}$$

Fig. 5 shows oscillographs taken of the induced current of the circuit, per Fig. 4. Curve 1 shows the current of the secondary circuit with the coil short-circuited and a voltage suddenly impressed on the

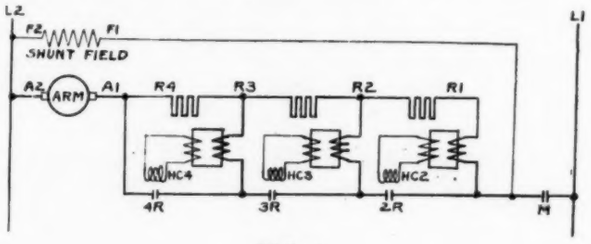

FIG. 6.

primary circuit. Curves 2 and 3 show the induced current in the primary and secondary, where the coils are energized from the same supply, but in opposite directions. The impressed voltages are of such value that the secondary coil determines the direction of the flux, when both coils are connected to the circuit. The secondary coil is then short-circuited, and the current is increased in the first circuit, due to the cutting out of the second coil. Curve 2 shows the current in the primary, and curve 3, the current in the secondary. It will be noted that the current in the primary decreases before it increases. This is due to the mutual inductance.

The induced transient current in the secondary is what is used as a means for governing the timing of the controller, and through it, the acceleration of the motor. The current can be used to control either relays or contactors. The device used is set to operate when the current is decreased to a certain value, which occurs after a certain length of time, depending upon the constants of the circuit. By

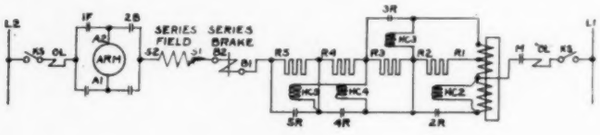

FIG. 7.

making the device controlled by the induced current adjustable as to the point of operation, the timing can be changed.

Fig. 6 shows connections for a controller utilizing a transformer for each step, each transformer having two coils, a primary and a secondary. The primary coil of the first transformer is in circuit when the main contactor closes. The secondary coil is connected in circuit with the holding out coil for the second accelerating contactor. The induced current in the secondary circuit, therefore, holds open this contactor for a certain length of time, until the induced current has decreased to a point at which the contactor is set to close. The primary coil of the second transformer is connected in circuit when the first accelerating contactor closes, and the secondary coil is connected in circuit with

the holding out coil for the second accelerating contactor. The coil of the third transformer is connected in circuit when the second accelerating contactor closes. The secondary coil is connected in circuit with the holding out coil for the last accelerating contactor. The induced current of the secondary delays the closure of the accelerating contactor, and thus the time is obtained. The time of acceleration can be regulated and changed by adjustment of the air gap in the magnetic circuit of the holding out magnet.

Fig. 7 shows connections for a controller utilizing one transformer having two coils. Due to circuit connections, the current first passes thru one coil, and then when the first accelerating contactor closes, it passes thru the second coil. When the second accelerating contactor closes, the current again passes thru the first coil, etc. In this way, the magnetic flux is reversed each time one of the accelerating contactors closes, and each coil acts alternately as a primary and a secondary. The holding out coils for the contactors are connected across the coil of the transformer used as the secondary in the different positions of the controller.

Fig. 8 shows a non-reverse controller with a transformer having three coils, TC2, TC3, and TC4. These coils are connected in circuit with coils HC2, HC3 and HC4, which are holding out coils for the

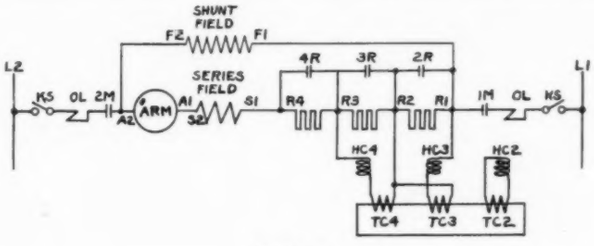

FIG. 8.

accelerating coils 2R, 3R, and 4R respectively. Coils TC3 and TC4 are subject to voltage across the accelerating resistance when the line contactors close. These coils are wound opposite to each other, so that a magnetic flux is set up, the direction of which is determined by TC3, and thus the current is induced in the coil TC2, similar to curve 1 in Fig. 5. The holding out coil HC2 is supplied with this induced current, which prevents the contactor 2R from closing for a certain length of time.

When the contactor 2R closes, TC3 and HC3 are short-circuited, and the flux in the transformer is reversed, due to coil TC4. The current in TC3 and HC3, therefore, decreases, similar to curve 3 in Fig. 5, and holds open contactor 3R for a certain length of time. When contactor 3R closes, coils TC4 and HC4 are short-circuited, and contactor 4R is held open by the induced current in the circuit, which is dependent upon the induction of the circuit and the mutual inductance.

The closing coils for the contactors are all connected in parallel without any electrical interlocks or relays between them. The only interlock required is one to insure that the closing coils are not energized much before the current is applied to the motor. Due to the induction of the closing coils, the adjustment of this interlock can stand for considerable variation.

In the oscillograph curves shown in Fig. 5, the voltage and current impressed on the circuit were constant. When a transformer is used with a controller for operating motors, the voltages impressed on the coil are not always the same, but vary with the load. The difference in load has more effect on the last accelerating contactor than on the first. The induced current controlling the first accelerating contactor is practically determined by the controller design, and the resistance layout determines the inrush current, which is always the same. The difference in load has, therefore, relatively little effect on the first accelerating contactors, with a properly designed controller. As the acceleration progresses,

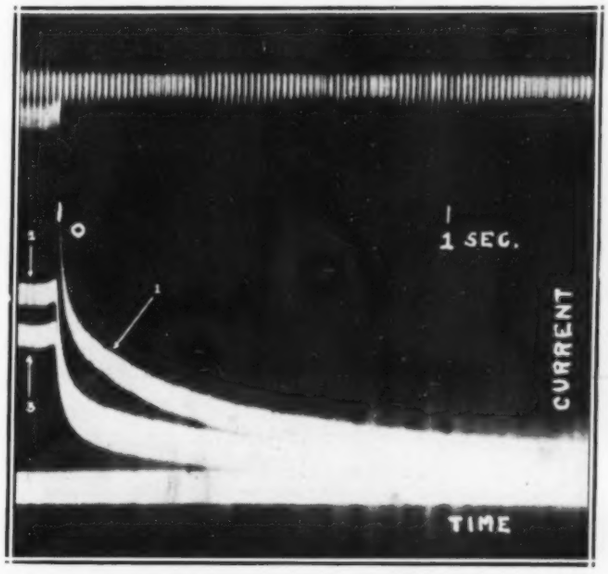

FIG. 9.

the difference in load has more effect on the accelerating current and the voltage impressed on the transformer coil.

When the inductance is constant, the transient current will be proportional to the impressed voltages and current. Where, however, there is iron in the circuit, this is not the case, as the inductance varies. Dependent upon the design, the induced current can be made to vary more or less in accordance with the load. It is possible to design control equipments, utilizing the inductive principles, having such circuit combinations and with the iron circuit having such magnetic densities that the timing is practically constant over a wide range in load. With a controller such as shown in Fig 7, a slight increase in time is, however, obtained when the load is materially increased.

Some indication of the effect of load variation in the later stages of acceleration or the induced current of a two coil transformer, per Fig. 4, with the coils wound opposite to each other, is given by the curves shown in Fig. 9. These curves show the induced current in the short circuited secondary coil, under three different load conditions. Curve #2 was taken with the motor driving full load, curve #1 with twice normal load, and curve #3, with one-half load, the controller being adjusted for normal load. It will be noted that in the case of curves #3, the impressed current before the coil is short-circuited,

does not decrease to one-half normal current. This is due to inertia in the motor armature and gearing, and the motor is still accelerating when the preceding accelerating contactor closes. Comparing the curves, there is little or practically no difference between curve #2 and curve #3 of the induced current under full load and half load condition. There is more difference between curves #1 and #2, indicating that for heavier load, the time delay on the controller is increased.

These curves show conditions with a two coil transformer and simply illustrate the general char-

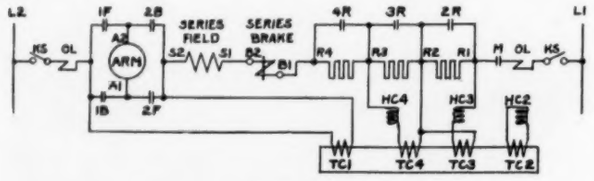

FIG. 10.

acteristics. On the actual controller, the curves are somewhat modified, as indicated later by accelerating current curves. They do, however, illustrate that this type of control differs from the ordinary time limit control, in that the load influences the time of acceleration to a certain extent, and the time is increased with heavy load, giving the motor a better chance to accelerate such loads.

Fig. 10 shows a three-step reversing controller, such as is used in connection with auxiliary mill

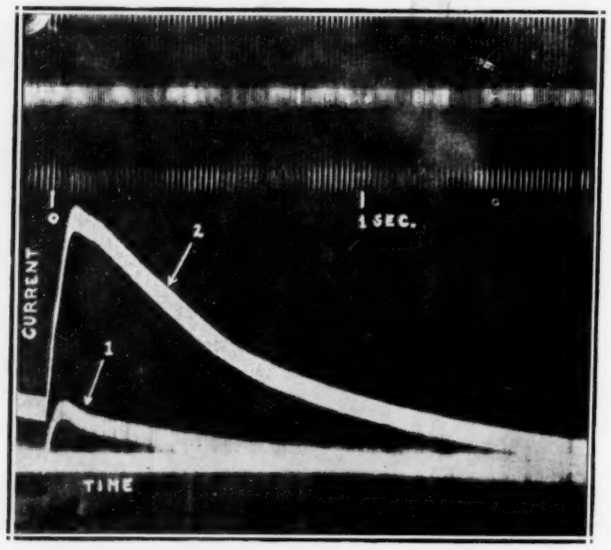

FIG. 11.

drive. This controller utilizes a single transformer, having four coils.

Three of these coils are connected in circuit with the holding out coils for the accelerating contactor, and the connections are similar to the connections shown for the non-reverse controller in Fig. 8.

Coil TC1 is connected across the motor armature outside of the reversing contactor. The function of this coil is to obtain different conditions on the first accelerating contactor when starting from rest and when plugging the motor. In a reversing controller, it is highly desirable that when starting from rest, the plugging contactor close immediately after the motor is started, and on plugging, that it does not close until the motor is practically at standstill. By so designing the transformer that there is considerable difference in ampere turns when starting from rest and when plugging the motor, and, further, by reversing the magnetic flux in the transformer when plugging, this feature can be readily obtained. With the coil TC1 connected across the motor armature, it has no effect when starting from rest, but is subject to motor voltage when plugging, and assists in building up the magnetic flux. The flux in the

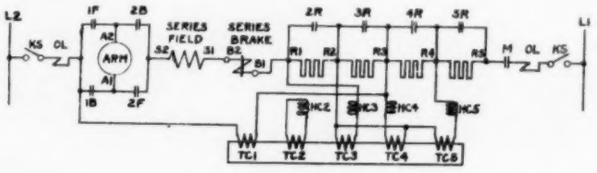

FIG. 12.

transformer before plugging, and the flux during the plugging period, are, further, in opposite directions. As the induced voltage is proportional to the rate of change in flux, this reversal increases the induced current. Similar effect is obtained with the connection shown in Fig. 7. Here the difference in flux or saturation during starting and plugging is obtained by a tap on one of the transformer coils.

Fig. 11 shows oscillograph taken of the induced current in the coil HC2, for the first accelerating contactor on the controller per Fig. 10. Curve 1 shows the current when the motor is started from rest, and curve 2, when plugging the motor, and a considerable difference can be readily noticed.

Fig. 12 shows a four-step reversing controller. Here the coil combination is slightly different from Fig. 11, in that coil TC1 is connected across the armature and part of the resistance. This is again done to obtain a difference in induced voltage for the holding out coil for the first accelerating contactor, thru the coil TC2, during starting and plugging. The basic idea of the transformer combination is to obtain a definite change in magnetic flux with the closure of the main and accelerating contactors. If there is no change in flux, the induced current will drop practically instantaneously. Inas-

FIG. 13.

much as the induced voltage is proportional to the rate of change of flux, the reversal of the flux on each succeeding step will give a longer time.

Fig. 13 shows the control connections of the controller shown in Fig. 12.

Fig. 14, 15, and 16 show accelerating current curves of what can be expected with a controller of this type under different load and operating conditions. This particular controller is set for a total accelerating time of approximately 1½ seconds, when starting from rest. The minimum time obtain-

able with a controller of this type is about .5 seconds, and the maximum, from 4 to 5 seconds.

Fig. 14 shows three accelerating curves; the upper one the accelerating current when starting the motor from rest with no load on the motor; the middle one when starting half load; and the lower one, when starting full load. Each of the curves further show the voltage across the motor armature, giving an indication of the speed of the motor as the ac-

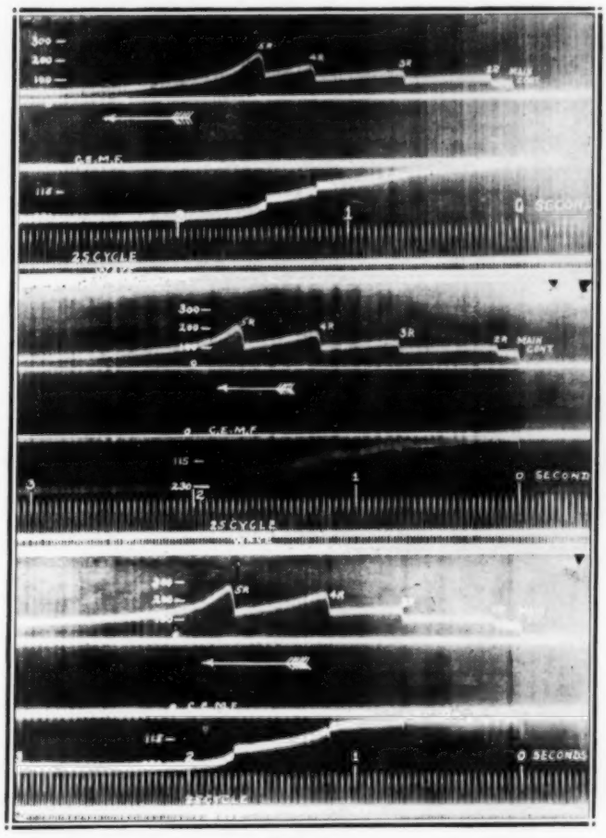

FIG. 14.

celeration progresses. The curves show a slight difference in the accelerating time between no load and half load, but very little difference between half load and full load.

Fig. 15 shows the accelerating current curve when starting twice normal load, and the current taken when attempting to start a stalled motor. From these curves, it can be seen that the time is increased on heavy load as acceleration progresses and the current becomes high, and that this time increases as the overloads become greater. The lower curves also show definitely that the controller continues to function regardless of load, until finally it is disconnected from the line by tripping of the overload.

Fig. 16 shows current curves when plugging the motor with no load and half load, and the increased time of the plugging contactor over that in starting from rest, shown in Fig 13, is clearly illustrated.

Controllers of this type have also been successfully applied to crane and bucket hoists. Here it is also desirable to be able to lift the maximum load in emergency, without having the controller designed and adjusted for maximum load at all times.

Figs. 17 and 18 show connections for a dynamic lowering bucket hoist having two series motors, one for the closing line, the other for the holding line. Fig. 17 shows the holding line controller, and Fig. 18 the closing line controller. The connections for closing and hoisting are similar in both controllers, and power is obtained by closing the M and P contactors, and the necessary accelerating contactors, depending upon the speed desired. For kick off and lowering, however, the connections are different. Power is obtained by closure of the M and 1 KO contactors, but the closing line is so arranged that the armature current is passed thru the series field by the closure of the 2D contactor, in order to obtain the high kick off torque by relatively low current from the line for opening of the bucket. On the holding line, this provision is not necessary. In retarding and lowering, the accelerating contactors

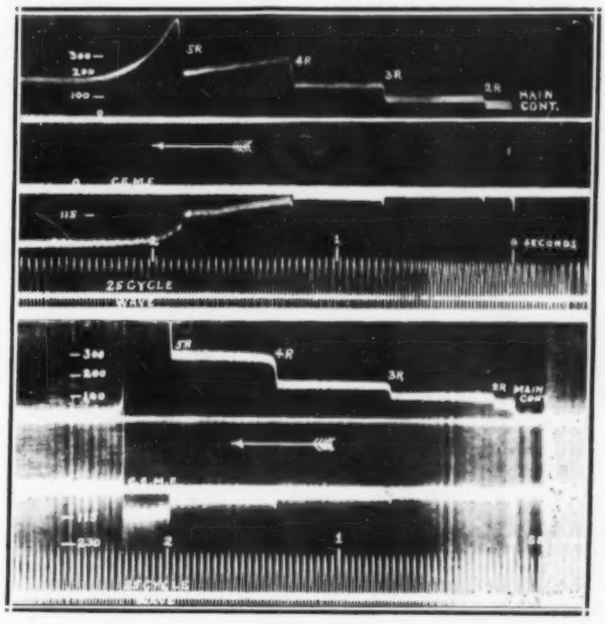

FIG. 15.

cut out the resistance in the dynamic braking loop. In the "off" position, the 2D contactor is closed.

Each controller is provided with a transformer having four coils for controlling the time of acceleration and retardation. The transformer connections are very much similar to those of the non-reverse controller, except that no holding out coil is provided on the first accelerating contactor. This contactor closes practically from the master controller.

Fig. 19 shows the connections for a dynamic lowering hoist for general purpose cranes. In the design of such a controller, it is necessary not only to take care of the hoisting and lowering conditions, but quick kick off must also be obtained when lowering the empty hook. Under this condition, the inertia of the motor armature and gearing must be accelerated, and provision must be made on the controller to take care of this.

In hoisting, the contactors M and P are closed, and the necessary accelerating contactors in sequence, depending upon the speed desired. In lowering, the 1 KO and 1D contactors are closed; also the necessary accelerating contactors. The contactors 5R and 6R are used partly to control the low-

ering speed and partly to insure proper acceleration and kick-off in connection with the 2 KO contactor. The 2D contactor is closed in the "off" position, establishing a dynamic braking loop around the armature and series field, setting the brake.

The controllers utilize a single transformer with five coils. Coils TC3, TC4, TC5, and TC6 are connected in circuit with the holding out coil for the

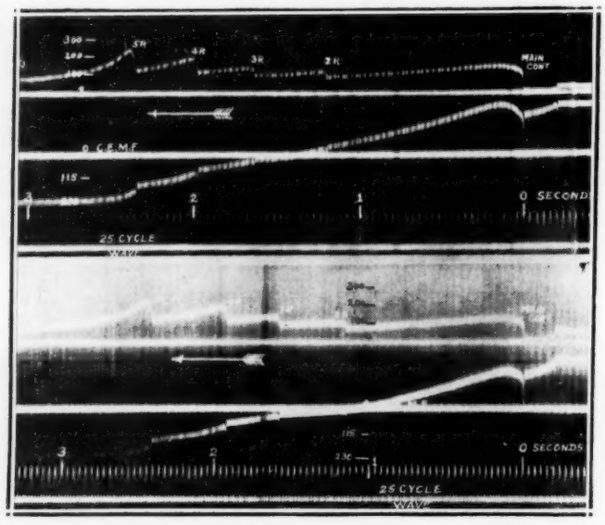

FIG. 16.

accelerating contactors, and control the closing of these contactors. TC1, TC3, TC4, and TC6 are subject to the voltage across the accelerating resistance, and produce the change in flux during the different stages of acceleration and retardation. Coil TC5 is connected in the closed circuit loop with the holding out coil for contactor 5R, so after the closure of the 4R contactor on acceleration and retardation, the induced current in this coil holds out the 5R contactor, for a certain length of time. Similar effect is also obtained in kick off for lowering when the master controller is thrown to the last position lowering for a quick start. Here again, the contactor is delayed in closing, due to the current in-

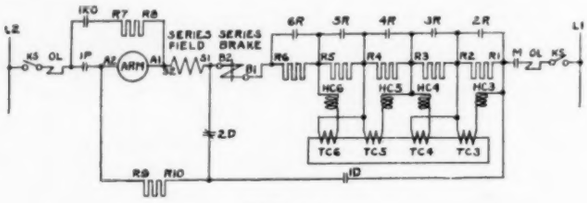

FIG. 17.

duced in the transformer coil TC5. The proper combination is obtained with interlocks on the 4R and the 2 KO contactors.

The trolley and bridge controllers are very much similar and do not differ materially from the reversing controllers previously outlined for auxiliary mill drives.

As far as the units entering into the design of the type of controller described are concerned, the main and reversing contactors are standard shunt contactors; the accelerating contactors are similar to the main and reversing contactors, except that they are provided with a holding out magnet having an adjustable air gap. This magnet acts on the main operating lever. The device; i. e., the transformer, which produces the time element, is extremely simple in construction. The timing obtained by it is not subject to change due to moisture or atmospheric conditions. There are no moving parts,

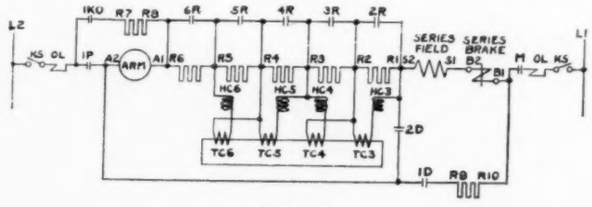

FIG. 18.

which are subject to change due to wear or tear, and when once properly connected to the controller, it requires no further attention for maintenance or adjustment.

In the foregoing, reference is made only to controllers for auxiliary steel mill drives and cranes. These controllers, however, are not limited to these particular applications, but are suitable for a great many other types of installations, such as charging

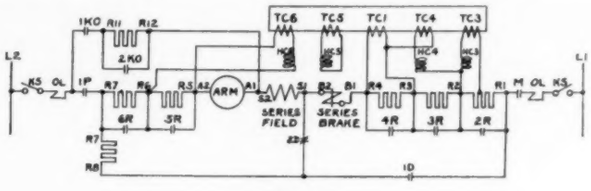

FIG. 19.

machines, coke oven machinery, conveyors, machine tools, skip hoists, and miscellaneous equipments in the iron and steel and other industries. In general, controllers of this type, utilizing the inductive effect to obtain the accelerating time, are most applicable where the service is severe and the accelerating time is relatively short.

DISCUSSION

W. B. Connally*: Is this type of control suitable for bridge work?"

N. L. Mortensen†: These controllers are satisfactory for bridge equipment on ordinary cranes.

"On high speed bridges, or on high speed trolleys on ore bridges, where there is considerable inertia, and the time for starting and stopping is comparatively long, it is a question of design and of the time required for starting and stopping. These particular controllers were designed primarily for auxiliary steel mill drives, where the time required is relatively short. This type of control can be designed so as to give a sufficiently long time for bridge and trolley equipments, but for specific installations, it may be simpler to provide current limit on the plugging contactor, as this is generally the one where the long time is required, rather than go to a special design."

J. E. Harrell‡: What is the life of one of the transformers used in this control?

*Chief Elec. Gulf States Steel Co., Alabama City, Ala.

†Asst. Chief Engr., Cutler Hammer Mfg. Co., Milwaukee, Wis.

‡Birmingham, Ala.

N. L. Mortensen: "There is no reason to expect that these transformers should not last indefinitely. On the shunt transformer, the coils are cut out with the accelerating contactors, and any coil connected across the motor has continuous duty."

J. E. Harrell: "Does the transformer have a solid core, and how is it constructed?"

N. L. Mortensen: "The transformer has a solid core. It consists, further, of two castings, and the three parts are bolted together. The castings are made of cast steel. In addition, it contains the necessary coils."

W. B. Connally: "Is the winding of the transformers made of fine wire?"

N. L. Mortensen: "The wire used is not particularly fine. Practically none of the windings are subject to full voltage, and the coils for 230 V. equipments are designed for about 1½ to 2 amperes. This is about the maximum current shown in the oscillographs."

A. L. Lemon*: "Do different rated motors require different transformers, or may one set of transformers be used for any size motor?"

N. L. Mortensen: "The size of transformers is the same for the same size of panel, for the same type of application. The larger panel has a larger transformer. For a certain size of panel, the same size of transformer is used for all mill and crane controllers. The windings in the case of shunt transformers are the same for all sizes of motors within the range of the panel, but different windings are used for different voltages."

J. E. Harrell: "Just what is the difference between the accelerating contactors and the main contactors?"

N. L. Mortensen: "The contact parts, blowouts, and closing coils are the same for both the accelerating and the main contactors. The main operating lever is different, and, of course, the accelerating contactors are provided with holding out magnets. All wearing parts are the same."

J. E. Sayre†: "How is the adjustment made to obtain the difference in time?"

N. L. Mortensen: "The adjustment in time is obtained by varying the pull of the holding out magnet, so that this magnet will let go at different values of induced current. This magnet is built in "U" shape, with an adjustable screw at the one end, and by varying the air gap between the screw and the main operating lever, the pull, and through it, the timing, are changed. There is an additional adjustment, by means of shims, for varying the other air gap, for coarser adjustment, depending upon whether extremely fast or slow timing is required. After this adjustment is once made, the screw adjustment will take care of the range on any particular installation."

*General Machinery Co., Birmingham, Ala.

†Asst. Chief Elec., Tennessee Coal, Iron & R. R. Co., Ensley, Ala.

J. E. Harrell: "What is the range of adjustment on this particular panel; that is, how much can the time of acceleration be varied?"

N. L. Mortensen: "The total time of acceleration can be varied from about .5 second minimum to 4 or 5 seconds maximum, for standard mill equipment. In special cases, this time can be increased about 50 to 100%."

W. B. Connally: "You do not, then, consider this type of control satisfactory for drives having considerable flywheel effect?"

N. L. Mortensen: "These controllers, as designed, are not satisfactory for drives having considerable flywheel effect and where a long timing is desired. While controllers of this type can be built to give a long time for acceleration, the timing can be generally obtained more cheaply by some other means."

J. E. Harrell: "How does the cost of a panel built up with these contactors compare with the cost of a panel using the present series relays for acceleration?"

N. L. Mortensen: "These controllers are somewhat more expensive; the difference amounts to about the cost of the transformer."

A. L. Lemon: "If the operating coil of one of these accelerating contactors should fail, would the following contactors close under time limit control?"

N. L. Mortensen: "In general that would be the case, but it might in some cases, result in two of the contactors closing at the same time, tripping the overload."

J. E. Sayre: "Is the transformer used with a reactance, such as is sometimes used on A.C. motors for starting?"

N. L. Mortensen: "The transformers are used to obtain the timing, and while, theoretically, the inductance will have a slight effect on the accelerating current peaks, similar to the inductive effect obtained from the series field, it is so small that the effect can be considered negligible for all practical purposes."

W. W. Garrett*: "If a control equipment is bought for a particular size of motor, could it be used on some other size motor, provided the contactors are of sufficient capacity to handle the current?"

N. L. Mortensen: "The control panel can be used for different sizes of motors, but the resistance will have to be changed to correspond to the motor rating."

*Engr., Tennessee Coal, Iron & R. R. Co., Fairfield, Ala

The Electrification of the Tata Iron Works at Jamshedpur

By S. GHOSH*

IT has been said that from the beginning of the human race its development has been dependent on its knowledge and ability to use POWER. POWER in this sense applies more to the power within the man for taking care of himself and in using this power in making others work for him. But let us take this "power" to mean electric energy, and it can well be said that the development of the steel manufacturing industry depends on its knowledge of and ability to make use of this power.

It is now about 35 years since electricity was first introduced into Steel Plants for motive power purposes, and for many years, it was a very small factor. At that distant time, the Tata Iron & Steel Company was not in existence and we have, therefore, in our developments been benefitted by the errors and successes of the pioneers in the steel business. The Tata Iron and Steel Company was formed in the year 1907 and the original plant consisted of 180 Coppee Coke Ovens, 2 Blast Furnaces, one 300-ton Hot Metal Mixer, four 40 ton stationary Open Hearth furnaces, one 40" two-high reversing blooming mill, one 28" Rail and Structural Mill, and a Bar Mill with necessary foundry and shops. Our generating equipment for this outlay consisted of three Escher-Wyss Turbo Blowers, three 1000 K.W. electrical generators and two 500 K.W. Motor Generator Sets. All these units were high pressure, condensing, steam driven and were fed from a boiler house containing sixteen 500 H.P. Babcock and Wilcox Boilers, six of which were coal-fired and the other ten arranged for burning either coal or Blast Furnace gas.

From time to time, certain additions were made to this original layout such as the enlarging of the two Blast Furnaces, the building of 50 Koppers Coke Ovens and 50 Drag Ovens, No. 2 Boiler House for burning waste gases from the Coppee ovens, a 1500 K.W. turbo-alternator, the addition of an independent steam engine for the 40" blooming mill, re-arrangement of the Bar Mills and the building of additional Open Hearth furnaces. The demand for iron and steel products was increasing, and it was finally decided to undertake the construction of new mills, Duplex Plant, additional Coke Ovens, etc., and whereas in the old plant electricity did not play a prominent part, in the new additions, electric power would be used wherever possible. This paper is therefore prepared with the view of putting before you the use of electricity in the manufacture of steel at the Tata Iron & Steel Company's Works located at Jamshedpur.

Raw Material

As the paper deals primarily with the electrification of the Works, I will not go into the details as regards the raw material but will only give you a brief outline of what is used and where it is obtained. As electrification over a wide area from a central source is still in its infancy in India, it is not possible at present to electrify all the holdings of the Company, and consequently, the mining operations cannot be considered on the same basis of that in other countries where electricity is available.

In considering the location of the sources of supply of raw material for the Tata Company, the question naturally arises why was the plant located at Jamshedpur thereby making necessary the transportation of Ore over 50 miles, Coal 120 to 150, Dolomite 120, Limestone 250, Chrome ore 50 miles and Manganese and Magnesite 500 and 1300 miles respectively. This question was the cause of considerable anxiety to the promoters, and the location was finally decided upon because of its nearness to Calcutta, ample land of suitable character was available, and the crowning point of all was the unfailing water supply furnished by the Kharkai and Subernarekha rivers which have never been known to run dry. This is a very important point in establishing a manufacturing plant in India where there are three months of hot weather with little or no rain and during which time a great majority of the streams become dry sand-beds.

The Iron Mines of the Company are located at Gurumahisani, Sulaipat and Badampahar in the Mourbhanj State. These mines are at an elevation of about 3,000 feet and far from coal and water. The ore is mined in open cuts with gravity inclines to lower the product to the bottom of the hill where it is loaded into wagons for shipment. During the year 1923, the total production of Iron Ore in India was over 800,000 tons, approximately 90 per cent of which was mined by the Tata Company.

The Coal for the Company's requirements is obtained from the Jharia and Raniganj coal fields partly from the Company mined property but the greater majority is purchased from other concerns. During the year 1923, the tonnage of coal mined in India amounted to approximately 19½ million tons, of which the consumption by Tata Iron Works was over 1 million tons. Dolomite, Limestone, Manganese and Magnesite are obtained from Company holdings, but the Chromite is purchased.

Coke Ovens

In the great process of steel-making, the first step to be considered is the manufacture of the coke. The Coke Plant of the Tata Company consists of the original 180 Coppee non-recovery retort coke ovens, 50 Koppers by-product ovens and 150 Wilputte ovens of recent construction (Figs. 1 and 2.) In connection with this plant is the coal and coke handling equipment which is completely electrified and provides for the economical handling of coal to the ovens and also for the quick quenching, screening and the despatching of the coke.

The coal-handling equipment is of the Robins conveyor Belt Type and consists of a hopper over

*Association C. M. S. T., M. I. E. E., A. M. I. Mech. E., M. Amer. I. E. E., Active Mem. A. I. & S. E. E., M. I. E. (Ind.), Chief Electrical Engineer, and A. K. Sen. Graduate, I. E. E., Electrician.

which the wagons are shunted and the coal dropped through chutes on to an electrically driven belt conveyor system which carries it to the crusher building where it is crushed and sorted, all the foreign materials being withdrawn by means of a magnetic separator, which separator is also electrically driven. The coal crushers are operated by 75 H. P., I. G. E. Motors and the Pulverizer by 300 H. P. motor of the same type and the control of these motors is also of the I. G. E. make. There are two charging lorries, each capable of taking a charge of coal sufficient to fill one oven, and are operated by 30 H.P., I. G. E. Motors. Two pusher machines are provided for pushing the Coke out of the ovens directly into the coke quenching cars and these machines are equipped with motors. After the quenching process, the car is hauled to a coke wharf where the side of the car is opened by air pressure and the coke automatically slides on the drying wharf. The coke wharfs are built on a slope and by raising a series of fingers, the coke is permitted to fall on another system of belt conveyors and carried to the screening station, where it is screened and dropped into wagons for shipment. For the recovery of coal tar and sulphate of ammonia, there is the usual layout consisting of primary coolers, tar extractors and saturators, ammonia stills, storage rooms, etc. Throughout the Coke Plant and the Sulphuric Acid Plant, there is installed a series of electrically operated controls for regulating the supply of gas and air to the ovens and for the conveyor system. For the operation of these ovens, there are installed 99 motors or a total of approximately 3500 H.P. and the power consumption per ton of coke averages 1.3 KWH.

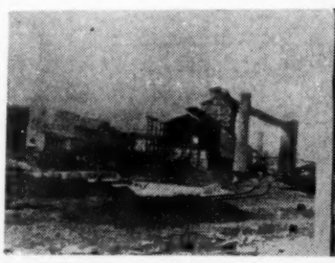

FIG. 1—The Willputte Coke Ovens.

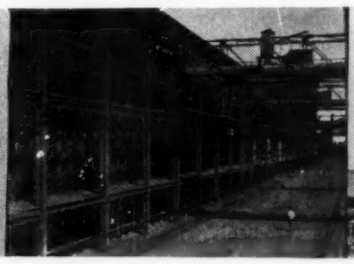

FIG. 2—Willputte Coke Oven Batteries.

FIG. 3—A. & B. Furnaces.

FIG. 4—Interior View of Furnace House.

Blast Furnace

The Blast Furnace department, as mentioned above, originally consisted of two furnaces known as 'A' and 'B', but during the War, the demand for Iron and Steel for war purposes so greatly increased that in order to supplement the output of Pig-iron and Ferro-manganese, the Company found it advisable to purchase Batelle Furnace in U. S. A. July, 1917, ship it to India and erect it there. This furnace is what is known now as 'E.' In the plan for the extensions to the Plant, provision had in the meantime been made for the erection of two more furnaces to be known as 'C' and 'D', and these were finally completed and blown in 'D' on 6th December, 1922 and 'C' on 15th January, 1924. The first two furnaces had (after the enlarging of the same referred to above) a rated capacity of 300 tons each per day. Batelle Furnace is of the same capacity, but the two new furnaces have a daily output of 500 tons each.

The old furnaces do not have sufficient electrical equipment to warrant discussion in this paper, but my remarks will deal primarily with the two new furnaces which are designed along the most modern lines and equipped with all up-to-date apparatus such as incline skip bridge and double skip with electrically operated skip hoisting engine and the bell control apparatus for automatically charging the raw materials into the furnaces. The raw material storage consists of a series of overhead tracks for the ore, Coke, and Dolomite, and are in line with the old stock bin system. The material is drawn through chutes into electrically operated lorry cars which weigh and report the weight of the charge before it is dumped into the furnace skip bucket and it is then carried by the electrically operated skip hoist to the top of the furnace and dumped.

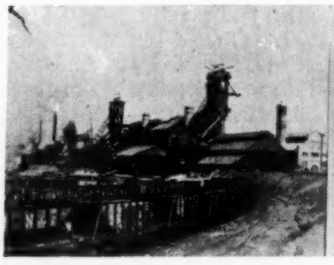

FIG. 5—New Blast Furnaces.

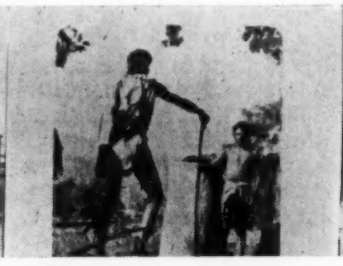

FIG. 6—Primitive Type of the Blast Furnaces.

FIG. 7—Platform Side of the Steel Furnaces.

FIG. 8—Discharge Side of the Steel Furnaces.

The blowing equipment for the three furnaces 'C,' 'D' and 'E' is found in Power House No. 2 and consists of three I. G. E. 45,000 Cu. ft. and one 37,000 Cu. ft. Turbo Blowers. This Power House which also formed part of the new extensions to the Works will be treated independently further on in this paper.

As it was considered not practical to cast the iron from the larger type of furnaces in the pig beds, it was necessary to provide a Pig Casting Machine, and

the equipment at this machine as well as in the Ladle House is all electrically driven.

The rated monthly production of the five furnaces is about 52,000 tons and this rating provides for an annual production of approximately 4,000 tons of Ferro-manganese which amount not only covers our own requirements but allows for the sale of this product. To handle this production there is provided an electrical installation consisting of six lorry cars, seven overhead cranes, and 28 miscellaneous motors totaling 750 H.P. and the average power consumption per ton of Pig-iron including the Pig Casting Machine is 36.3 KW. hours.

In this connection, your attention is called to Figs. 3, 4, 5, and 6. The first two figures show the general view of the old blast furnaces the third figure shows the new furnaces and the last mentioned figure is of a primitive type of Blast Furnace. The remains of a number of these primitive type blast furnaces have been found at various locations in India and in some localities they are still in use. In fact, up until about one year ago, the actual furnace of the photograph was in use just about two miles from Jamshedpur.

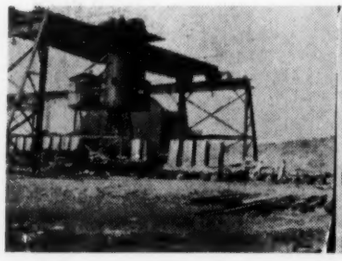

FIG. 9—Stripper Crane Duplex Plant.

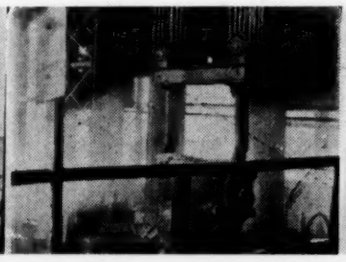

FIG. 10—Ladle Crane Duplex Plant.

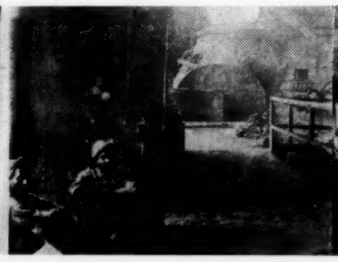

FIG. 11—Bessemer Converter.

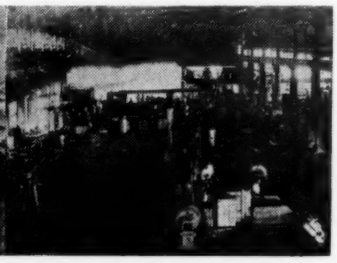

FIG. 12—Old Bar Mills.

The hot metal from the furnaces can be sent in four different directions, either to the sand-beds or pig casting machine for making into pigs, or to the old Open Hearth or the new Duplex Plant for the manufacture of steel. The original plans provided for the building of the Duplex Plant adjacent to the old shop so that the iron could be charged into the mixer and furnaces on the charging side of the furnaces. This was, however, abandoned and the Duplex Plant was built in another location about one mile from the old plant. In this paper, the old plant will be referred to as the Open Hearth and the new one as the Duplex.

Open Hearth

In the Open Hearth Department is found a 300 ton mixer and seven stationary furnaces, four of 60 ton capacity, two of 40 and one of 80 (Fig. 7.)

The ladles of molten metal are conveyed from the Blast Furnaces to the Open Hearth by means of a steam locomotive and it is poured either into the mixer or direct into the furnaces. After conversion, which takes on an average of from 8 to 10 hours, the metal is cast into 5-ton ingot moulds (Fig. 8.) A portion of this steel is for rolling in the old Blooming Mill adjacent to the Open Hearth and these ingots are stripped and soaked in the old Plant. But the steel from this shop which is to be rolled in the New Blooming Mill is sent to the Duplex Stripper (Fig. 9) in the moulds and stripped there after which it is sent to the pits at the new Blooming Mill. The average monthly production of steel in the Open Hearth furnaces is approximately 17,000 tons, and the electrical equipment for handling same consists of one 100 ton ladle crane, two-75 ton ladle cranes, two floor type chargers and 3 stockyard cranes.

Duplex Plant

In connection with the Duplex Plant, we have the mixer and Converter unit which consists of a hot metal mixer of 1300 ton capacity served by a 100 ton 72 ft. span Alliance ladle crane (Fig. 10.) This crane lifts the Blast Furnace ladles from their trucks, and by means of a 25 tons auxiliary hook tilts the ladle and pours the contents into the mixer. From the mixer, the metal is poured into the ladles mounted on trucks, weighed and propelled by rope haulage to either of the two Bessemer Converters. Here the metal is poured into the Converters with the aid of a 17-ton jib crane. In these Converters, the metal is blown by means of air blast introduced through tuyeres in the Converter bottom for a period of about 15 minutes to remove the silicon and reduce the carbon. The Converters then tilt and charge into a ladle, and this is hauled by a steam locomotive to the Duplex Open Hearth Plant (Fig. 11).

To provide for the air blast referred to above, there is installed a separate blowing engine-house equipped with two I. G. E. 25,000 Cu. ft. electrically driven blowers, the motors of which are I. G. E. Mill type induction 3600 H.P. capacity, running at 750 RPM. There is also a 500 KW. Motor Generator Set for supplying 220 volt D.C. power for cranes, tilting motors, etc., and a 600 KVA. Transformer bank for supplying 440 volts A.C. Power for the Gas Producers.

In the operation of Bessemer Converters, it is necessary to frequently change and reline the converter bottoms, and for this work, there is provided a Bottom-House which contains the necessary machinery for preparing the material for this relining. This machinery consists of a crusher, dry and wet pans and drying ovens as well as pumps for heating the drying ovens and for the accumulator for the operation of the jack cars. The main building is served by 25-ton 60 ft. span Alliance Crane and the lean-to by a ten ton 20 ft. span Alliance crane.

The blown metal from the Converters is charged into one of the two tilting furnaces where it is made into steel by the addition of ore, pit scrap and flux. In these furnaces, the phosphorus and sulphur are removed and the heat brought up to the required carbon content. This process requires approximately

four hours from tap to tap, and the average monthly production of this plant has been approximately 20,000 tons.

The electrical equipment in connection with the two tilting furnaces consists of a 3½ ton Alliance low type charging machine for handling the charging boxes containing the ore, pit scrap and the flux, a 100 ton 75 ft. span Alliance ladle Crane for conveying the ladles from the Converters to the furnaces, two 150 ton 70 ft. span Alliance ladle cranes for handling the ladles from the furnaces to the ingot moulds and one 40 ton Alliance crane for cleaning up the casting bed, one 150 ton 75 ft. span Alliance crane for stripping the ingots, two 10 ton 100 ft. span Alliance double trolley travelling cranes for handling the grab buckets and lifting magnets in the stockyard, one 25 ton Alliance travelling crane at the Skull Cracker and 25 ton fast travelling trolley, and both this crane and trolley are equipped for handling the steel skull cracker ball with magnets.

There is also an adjacent Calcining Plant consisting of crushers, two-8-inch diameter rotary kilns and two 6-inch diameter coolers with the necessary bins and conveying apparatus for both the raw and finished material.

The furnaces are fired with producer gas made in an adjacent Producer Plant which consists of 8 Morgan Automatic Gas Producers with the necessary coal and ash handling apparatus.

Old Rolling Mills

The old 40″ Blooming Mill was built directly in line with the Open Hearth and the ingots are taken from the pits, placed on an electrically operated buggy and conveyed to the Blooming Mill where they are rolled into blooms for Rail Mill, billets for Bar Mill, and slabs for Plate Mill. There is a 28″ Rail Mill operated in conjunction with this Blooming Mill, and these two Mills, together with the old Bar Mill, are all of antiquated design and steam-driven (Figs. 12 and 13). The electrical equipment consists only of approximately 50 motors with a combined H.P. of 1104. There are 3 ordinary overhead cranes, one Soaking Pit charging crane and one Rail Mill Charging Crane.

During the time intervening between the building of the old mills and the laying out of the new mills, great strides had been made in the electrification of steel mills and it had been proved beyond a doubt that the application of electric driver secures the most practical and economical method of power generation.

The original installation of motors for rolling mill drives was made in 1905 at the Edgar Thomson Works, Pittsburgh, Pa., U. S. A., and consisted of two 1500 H. P. Westinghouse D.C. Motors connected to the main rolls of a light Rail Mill. (Fig. 14). These motors were non-reversing, as it was considered at that time that reversing motors were not applicable to these conditions. Later developments, however, disproved this theory, and in 1907, the Westinghouse Company furnished a 8000 H.P. reversing mill drive for the Illinois Steel Co. for operating a 30″ Universal Plate Mill at their South Chicago Works (Fig. 15). The success of these two installations proved the dependability and efficiency of electric drive and progress along these lines developed very rapidly from that time.

New Mills Blooming Mill

The new mills of the Tata Company are completely electrified, but as they have not been running at full load capacity for a sufficient length of time, it has not been possible to obtain accurate load figures and performance curves. The figures used have been obtained on tests with the mill running underload for a short period of time only. These figures will no doubt be greatly improved when operating conditions improve and it is possible to run continuously at full load and after the operators have familiarized themselves with the mill equipment. It has been necessary to train all the men for operating these mills and it must be borne in mind that such things cannot be learnt overnight, but the successful operation of these mills require familiarity with the equipment and practice in the operation of same.

The new 40″ Blooming Mill and the 18″ Sheet Bar and Billet Mill are located in one building and so arranged that blooms for the Rail and Structural Mill, billets for the Merchant Mill, slabs for the Plate Mill, sheet bar for the Sheet Mill, tin bar for the Tinplate Company, and sleeper bars for the Sleeper Plant, can be rolled direct from ingots.

The Blooming Mill is a 40″ Mackintosh Hemphill two high reversing Mill (Fig. 16) with a rated capacity of about 1000 gross tons per 8-hour shift. This mill rolls ingots 21″x33″ weighing approximately 21,000 lbs. to 8″x8″ blooms in 20 passes. The average power consumption is 31.1 K.W. hour per ton of finished blooms. The slab ingots 21″x43″ are rolled down to 9″x38″ slabs in 16 passes. The ingots are carried from the Soaking Pits to the Rolling Mill ingot table by means of an electric ingot buggy. The mill is served by motor-driven roll tables on the entry and delivery sides and is equipped with a hy-

FIG. 13—11000/12000 Reciprocating Steam Engine of Old Blooming Mill.

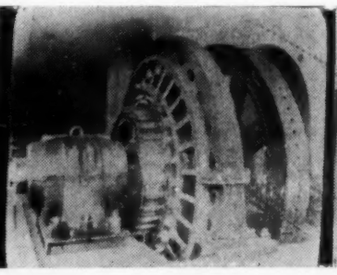

FIG. 14—1500 H. P. D. C. Motor.

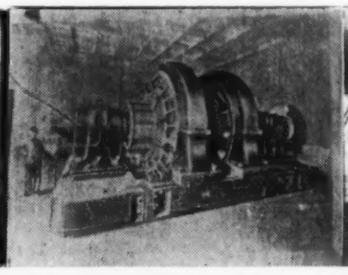

FIG. 15—3000 H. P. Reversing Mill Drive Motor.

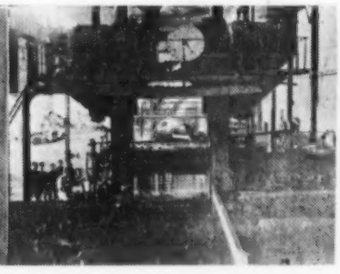

FIG. 16—New Blooming Mill.

draulically-operated manipulator on the entry side only. The slabs and blooms are sheared into the required lengths by means of a hydraulic vertical shear in the delivery table and the crop ends drop in a chute on to a conveyor and are carried under a floor to wagons for shipment to the Open Hearth. Following the shear, the rope transfer carries the material to be finished in the Rail and Structural Mill to a broadside transfer table from which it is sent either direct to this Mill or to the re-heating furnaces.

Rail and Structural Mill

The Rail and Structural Mill is of the Mackintosh Hemphill design consisting of an Intermediate train of two stands of 3-high rolls 30″ diameter for roughing 20″x24″ beams and 28″ diameter for all other sections (Fig. 17). These stands are served by 4 travelling lifting tables, two on each side of the mill. The Finishing Mill consists of a single stand of 28″ two-high rolls. This is a combination Mill and has a rated capacity of about 850 tons per 8-hour shift.

Rails after leaving the finishing stand are cut to lengths by four adjustable hot saws, pass through a cambering and a stamping machine on to the hot bed then on to the rail finishing shed where they are straightened, gagged, ended and drilled. Finished rails then pass outside the building to a dock where they are inspected and loaded. For rejected rails there is provided a cold saw for re-sawing and re-finishing.

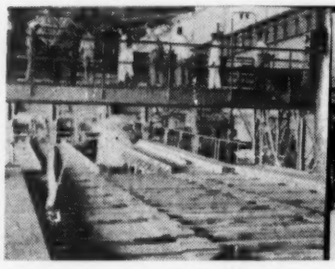

FIG. 17—New Rail Mill.

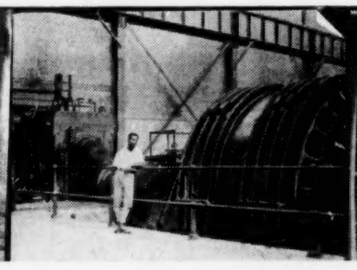

FIG. 18—New Blooming Mill Motor — Blooming Mill Motor House.

FIG. 19—Interior of Blooming Mill Motor House.

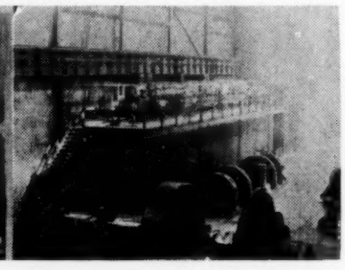

FIG. 20—Blooming Rail Mill Motor House Switchboard.

Sheet Bar and Billet Mill

Beyond the broadside transfer table referred to above there is a roller table which delivers the blooms to a six stand 24″ Morgan Continuous Mill where they are rolled down to 8″x2″ slabs. These slabs pass over a roller run table and through a six stand 18″ Morgan Mill where they are rolled into sheet bar. Beyond this mill there is a flying shear for cutting the bars into proper lengths and a bar piler for piling them ready to be handled to the cooling bed. This Sheet Bar and Billet Mill is capable of rolling billets from 1″ to 5″ for the Bar Mill or Merchant Mill, and also roll sheet bars for Sheet Mill from 8″ to 12″ and sleeper sections up to 16″ width.

The electrical drives for all these mills are located in separate motor houses and consist of the following equipment: (Figs. 18, 19, 20 and 21).

Two—I. G. E., 1500 K.W. Self-synchronizing motor generator sets and one 1200 KVA Transformer bank for furnishing 250 volts D.C. and 440 volts A.C. Power for the Mill and Auxiliaries.

One—I. G. E., Flywheel M. G. Set for the Blooming Mill Roll Drive Motor consisting of three D.C. Generators 2000 K.W. each, one 4000 H.P. Induction Motor and one Flywheel.

One—I. G. E., Flywheel M. G. Set for the Rail Mill Roll Drive Motor consisting of two D.C. Generators 3750 K.W. each, one 6500 H.P. Induction Motor and Flywheel.

One—I. G. E., 5600 H.P., D.C. Mill Drive Motor for Blooming Mill.

One—I. G. E., 6300 H.P., D.C. Mill Drive Motor for the Rail Mill.

Two—I. G. E., 150 K.W. Motor Generator Sets for exciting the fields of the Flywheel M. G. Sets and Mill Drive Motors.

Three—I. G. E., 300 H.P. High Tension Motor for the Hydraulic Pumps operating the Tilting Tables, shears, etc.

One—50 Ton Overhead Crane with a 15 Ton Auxiliary Hoist.

An air conditioning plant for providing forced ventilation for the motor after being washed.

The Sheet Bar and Billet Mill Consists of:

Two—I. G. E., 3000 Volts Induction motors—one 2300 H.P. driving the 24″ Mill and the other 4000 H.P. driving the 18″ Mill.

One—30 Ton Overhead Crane.

Plate Mill

Ingots or slabs from the Blooming Mill are delivered on wagons to a storage yard adjacent to the Plate Mill. A 15-ton 97-ft. span Alliance crane lifts them up and places them alongside the furnace building where they are picked up by the 8-ton Alliance revolving charging cranes and placed in the heating furnaces. These heated slabs are then taken out of the furnace by the charging cranes and conveyed to the Mill by means of a rope-propelled slab car.

The Plate Mill is a 96-in. United Engineering and Foundry Company's Tandem Mill consisting of a 3 high roughing stand followed by a 3 high finishing stand, each stand equipped with hydraulically operated lifting tables front and back of the Mills (Figs. 22 and 23). Each stand is directly driven through a set of Falk speed reducing gears by a I. G. E. motor and each drive set has a 15-ft. flywheel. After leaving the finishing stand, the plates pass over loaded tables through a straight roll Newbold straightening machine, after which they are cooled on a chain conveyor and passed to an inspection table.

The roughing stand motor is a 2000 H.P. 200 R.P.M., 3000 Volts I. G. E. Induction type, and the finishing stand is a 2500 H.P., 200 R.P.M., 3000 Volt Motor of the same type (Fig. 24). These Motors are located in a separate motor-house (Fig. 25), which also contains a 750 K.W. Synchronous motor generator set for supplying D.C. power for cranes and roller runs, one bank of 600 K.V.A. transformers stepping down the voltage from 3000 to 440 for A.C. supply and two hydraulic pumps driven by 250 H.P. 3000 volts induction motors for supplying hydraulic power for the shears and tilting tables. This motor-house is served by a 30-ton 65-ft. span Alliance Crane.

There are seven electric cranes in this department and 66 motors forming a total of approximately 7750 H.P. The power consumption on the main mill motor averages 74.8 K.W. hours per ton of finished plates.

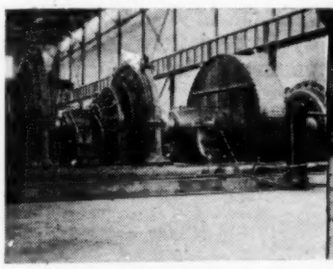

FIG. 21—Flywheel M. G. Set—New Blooming Mill.

FIG. 22—Plate Mill.

FIG. 23—Plate Mill.

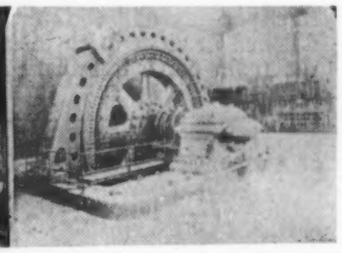

FIG. 24—Plate Mill Motor.

Merchant Mill

Billets from the Sheet Bar and Billet Mill are placed by the stock yard crane on a furnace charging conveyor extending into the stock yard for mills and sent through a Morgan continuous heating furnace. The heated billets are pushed out of the furnace and a set of pinch rolls forces the material through a flying shear. From this point it passes through a Merchant Mill of Morgan design (Fig. 26) consisting of a 16-in. edging mill, preceding 6 stands of continuous 14-in. mill and a cross country type 12-in. mill of 2 trains, 2 stands each. There is also an auxiliary 8-in. finishing mill consisting of 2 stands in line with the second train of the 12-in. mill. This auxiliary mill is for the rolling of rods and similar small sections. Following this is an Edward's escapement type cooling bed 350 feet long and a bar shear, and at the end of the bar shear table is located a roller straightener. This mill is capable of producing ¼" rods, ¼ to 2-inch rounds, and squares, ¾"x8" to 4½"x¼", and thicker flats and 1"x⅛" to 3"x¼" angles.

The mills and equipment are served by a 15-ton 95-ft. span Alliance crane. The main Merchant Mill is driven by a 2500 H.P., 3000 volt G. E. Motor with speeds of 450/375/300 R.P.M. equipped with a Sherbius System of control.

There are 6 electrical cranes in this Mill, 36 motors totalling 4,422 H.P. The power consumption averages 55 K.W.H. per ton of finished product.

FIG. 25—Main Motor for the Plate Mill.

FIG. 26—Merchant Mill.

Sheet Mill

The Sheet bars are delivered to the approach table at the bar shear and after shearing are placed in the heating furnace by the furnace building crane. The sheet mill is of United Engineering and Foundry design consisting of four 30-in. hot mill stands, nine 30-in. finishing stands and two 30-in. cold stands. (Fig. 27).

These mills are driven by a 1500 H.P., 3000 volt I. G. E. induction motor connected through a flexible coupling and running at 346 R.P.M. at full load with a speed reduction of 9 to 1 which gives a nominal mill speed of about 26 R.P.M. There are 6 sheet furnaces, 6 pair furnaces and 3 combination sheet and pair furnaces all with water-cooled fronts, mechanical stokers and blowers equipped for coal-firing (Fig. 28). The furnaces are charged by hydraulic pushers operated by hydraulic pumps and accumulators. This furnace building is served by a 15-ton 57-ft. span Alliance crane.

FIG. 27—Stands of Rolls—Sheet Mill.

FIG. 28—Furnaces—Sheet Mills.

The auxiliary equipment in the mill building includes a 66-in. motor-driven hot sheet leveller, one 126-in. motor-operated square inch shear, a scrap baling press with mono-rail and magnet for handling baled scrap. The mill proper is served by a 30-ton 97-ft. span Alliance crane, and the annealing end of the building is by 50-ton 97-ft. span crane. Figs. 29 and 30 show an annealing furnace and a

Pickling Machine situated on the annealing end of the building.

The floor of the mill is water cooled and washed air is supplied for cooling purposes. An air outlet nozzle has been provided for each stand of rolls and for each bar and finishing furnace and these nozzles are adjustable thereby permitting the flow of the air being directed wherever required.

In this mill are produced plain black sheets, as well as galvanized and corrugated sheets. (Figs. 31 and 32).

The total production of this mill averages 120 tons per day and the power consumption per ton of finished product is on an average of 126 K.W.H. on the main drive but there is a wide variation in the figures obtained, ranging from 80 K.W.H. to as high as 160 K.W.H.

There is a total of 37 Motors, representing an installed H.P. of 2042 and in addition there are five overhead cranes.

FIG. 29—Annealing Furnace — Sheet Mill.

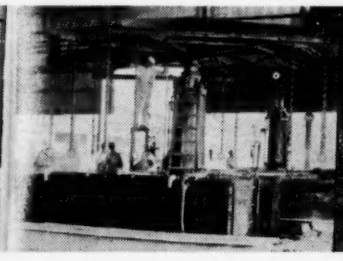

FIG. 30—Pickling Machine—Sheet Mill.

FIG. 31—Galvanizing Plant—Sheet Mill.

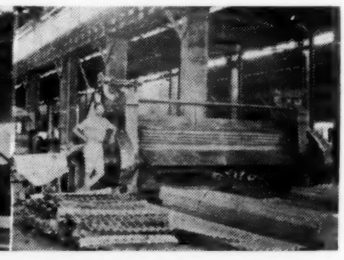

FIG. 32—Corrugating Machine — Sheet Mill.

General

The distribution system has been extended throughout the works and electric power is available wherever required (Figs. 33 and 34). All the shops are equipped with motor driven tools, either direct connected or belt driven.

On the total electrical system there are connected 981 motors representing 77.815 H.P. and 88 overhead cranes.

The lighting of the works is taken care of by about 8000 lights varying in capacity from 16 c.p. to 1000 c.p. Due to the extreme hot weather it is necessary that a large number of fans be provided as each office must be equipped with one or two ceiling fans.

The electric power for use in the town is also provided from the Company's Power Stations. This power is distributed at 220 volts A.C. and D.C., and takes care of approximately 1600 fans and 7000 lights.

The supply of water for the Works and also for the large population living in the adjacent area is made by pumping from the Subernarekha river which is at a distance of two miles. There are five Sulzer High Lift Pumps each of 4 million gallons capacity per diem at a head of 170 ft. These are driven by 250 H.P., 3000 Volts, 980 R.P.M., vertical type induction motors as shown in Fig. 35. Fig. 36 shows one of the water Reservoirs of the Town Water Supply System.

The town is supplied with water filtered by the Jewel Filter System, and the water is pumped from the Town Pump House (as shown in Fig. 25) to the Central Reservoir (Fig. 26) from where it is distributed. The town pumps are Sulzer Horizontal type pumps of 2,160,000 gallons per diem at a head of 205 ft. and are driven by 3 Induction Motors of 145 H.P.

In addition to the supplying of power for Works and Town use there is an additional load of about 5000 Kilowatts carried on the Power House for certain Subsidiary Companies whose plants are situated in the district.

Power Stations

There are two power generating stations known as No. 1 and No. 2, with a total generating capacity of approximately 38,000 K.W. No. 1 was the original station and is located near the Open Hearth Department in the old mills (Figs. 37 and 38). No. 2 is located near the Blast Furnace and was built to take care of the new additions to the Plant (Figs. 39 and 40). These stations are at present operated as individual units, but preparations are being made for the installation of a tie-line which will make it possible to feed one into the other and allow for a better distribution of the plant load.

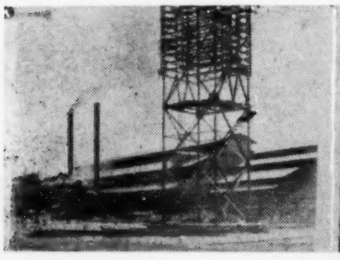

FIG. 33—H. T. Junction Tower.

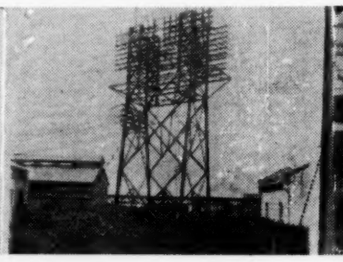

FIG. 34—H. T. Transmission Tower.

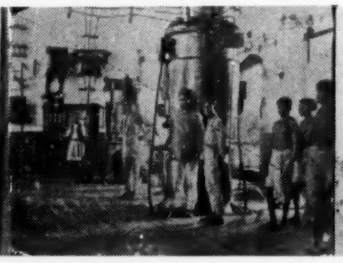

FIG. 35—Interior View of the River Pump at the Subernarekha.

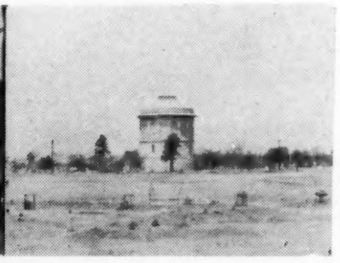

FIG. 36—General Water Reservoir.

Station No. 1

Station No. 1 is a two-storied building: Upper story 240′ long x 72′ wide and 34′ high contains all

electrical and blowing equipment. Lower story is 20′ high and contains all condenser, service, Hydraulic and Air Pumps, bulk of electrical wiring between electrical units and switchboard and steam water pipes. One wing building south east 46′ long x 39′ high x 27′ wide contains one Turbo-pump and D.C. Service Pump, one H. T. Boiler Feed Pump and H. T. Service Pump. One wing building south-west contains one Booster Pump for Kudma Reservoir. One lean-to on west contains one No. 4 Transformer. One North east extension contains one 4200 K.W. Set.

The equipments in this station are as follows:

3—Escher Wyss Turbo Blowers with blowing capacity of from 25,000 cft. against 24 lbs. to 40,000 cft. against 15 lbs. pressure.

1—Ingersoll Rand Turbo Blower with a blowing capacity of 25,000 cft. against 20 lbs. pressure and 35,000 cft. against 15 lbs. pressure.

2—A. E. G. 1000 K.W. 3 phase, 50 cycles, 3000 volts Generator with direct coupled exciter, driven by 8 Stage Impulse type Zeolly steam Turbine capable of continuous load of 1250 BHP. at 180 lbs. steam pressure and 27″ vacuum.

1—British Westinghouse, 1500 KW. Turbo Alternator, 3000 R.P.M., 3000 Volts, 50 periods, 3 phase, direct coupled to a Exciter driven by Westinghouse Hateau Steam Turbine capable of continuous load of 2000 BHP. at 160 lbs. steam pressure per sq. in. and 27″ vacuum.

1—British Thomson Houston 5000 KW., 3000 RPM. 3000 volts, 50 periods, .8 power factor, Turbo Alternator with direct coupled Exciter driven by Curtis H56 type steam Turbine capable of continuous load 6700 BHP at a steam pressure of 175 lbs. 27″ vacuum and 100° superheat.

1—International General Electric 4200 K.W., 1500 R.P.M. 1012 amps., 3000 volt, 50 periods, 3 phase, Turbo Alternator with direct coupled Exciter driven by Curtis Steam Turbine, Form J, capable of continuous load of 5600 BHP at a steam pressure of 175 lbs. and 27″ vacuum.

2—A. E. G. 500 KW. Motor Generator, each consisting of 3 phase, 50 periods, 3000 volts, 128 amps. Induction Motor operating at 500 RPM., coupled to one continuous current shunt Dynamo 250 volts, 2000 amps.

1—I. G. E. 750 KW. Self-synchronizing motor generator, consisting of one 3 phase, 50 periods, 3000 volts, 211 amps., synchronous motor operating at 750 RPM. coupled to one continuous current compound wound Dynamo (series winding) short-circuited 250 volts, 3000 amps.

1—Bellis & Morcom Vertical High speed compound, non-condensing engine, direct connected to continuous current shunt wound Dynamo, 250 vs. 600 amps., operating at a speed of 440 RPM. (Station lighting).

3—1250 KVA. I. G. E. Transformer Bank, 3000/447, 5 vs. 234/1570 amps. 50 periods, 3 phase, oil immersed, self cooled, shell type, each consisting of three-single phase transformers banked together and connected in Delta on both High Tension and Low Tension sides to give 1000 KW.

1—1200 KVA. I. G. E. Transformer Bank 3000/440 volts, 3 phase, 230/1570 amps. oil immersed, self cooled, shell type. This transformer consists of 6-200 KVA single phase, banked together two in parallel and connected delta on both High Tension and Low Tension sides to give 1000 KW.

9—Condensers for the Turbo Blowers and Generators.

1—5000 K.W. Condensing Plant.

1—4200 K.W. Condensing Plant.

5—Motor driven and two steam driven service pumps capable of pumping a combined load of approximately 22,000,000 gallons in 24 hours.

4—Hydraulic Pumps with direct coupled 150 H.P., A. E. G. Induction Motor delivering 960,000 gallons in 24 hours.

3—Boiler Feed Centrifugal Pumps, one of which is a Plunger Pump, one direct coupled to a 132 H.P. slip ring induction motor and one is a 300 K.W. 1470 R.P.M. 3000 volts Pump.

Two Pumps for supplying water to the town are located in this building and consist of two horizontal centrifugal units. There is also one Worthington pump which is spare for the boiler feed and town supply. There are also two units for pumping water into the filter beds. These are low pressure centrifugal pumps driven by direct coupled 10 H.P. slip ring induction motor.

FIG. 37—Power House No. 1. FIG. 38—Interior of the Old Power Plant. FIG. 39—Power House No. 2. FIG. 40—Interior of the New Power Station.

Station No. 2

Station No. 2 is a two-storied building: Upper story contains the blowers, generators and switchboard. Lower story contains condensers, pumps, steam and water piping, storage battery and bulk of wiring between electrical units and switchboards, the size of the building is about 64′ x 432′.

The equipments in this Station are as follows:

2—Turbine driven Centrifugal Blowers, capa-

ble of delivering 45,000 cft. of air per minute at a pressure of 15 lbs.

2—36,000 cft. of air capacity Turbine driven Blowers under construction.

1—5000 KW. I. G. E. Turbine Driven Generator, 3000 RPM. 3000 volts, 50 cycles with Wheeler Low Level Jet Condenser, capacity 65,000 lbs. per hour.

2—10,000 KW. I. G. E. Turbine driven Generators, 1500 RPM., 3000 volts, 50 cycles with Wheeler Multinozzle Jet Condenser, capacity 153,000 lbs. steam per hour each.

1—I. G. E. 750 KW. Self-synchronizing motor generator consisting of 1—3 phase, 50 cycles, 3000 volts, 211 amps., 750 R.P.M. Synchronous motor coupled to 1 Continuous current Dynamo, 250 volts, 3000 amps.

6—200 KVA., I. G. E. 3000/480/440 volts, 115/720 amps. 50 periods, single phase transformer banked together and connected in Delta on both H. T. and L. T. sides to give 1200 KVA.

1—50 KVA., I. G. E. 3000/220/110 volts, 16/220 amps. 50 periods, single phase, oil-immersed, self-cooled, shell type Transformer for station lighting.

1—440 volts 50 periods squirrel Cage Induction Motor, 1500 RPM. Direct coupled to a shunt wound Battery charging Generator, 50-200 volts, 25 amps.

1—440 volts, 50 periods, 150 H.P. Squirrel Cage induction Motor direct coupled to a 100 KW. 125 volts, 800 amps. Compound wound Emergency Exciter Generator.

For operating remote control switches and emergency lights there are 60-Ell type cells capable of giving out 110 ampere hours at 125 volts.

General Water Supply For Works

Service water for the East Plant Mills and Condenser Water for Power House No. 2 is supplied by Pump House No. 2 which consists of 6—20″ Alberger Double Suction Turbo Condenser Pump, 750 RPM., 12,000 gallons per minute against 35′ total pumping head and 10′ suction lift, each direct coupled to a synchronous motor 150 H.P. 3000 volts.

4—18″ Alberger Double Suction Turbo Service Pumps, 750 R.P.M., 12,000 gallons per minute against 145′ total pumping head and 10′ suction, each direct coupled to 600 H.P. I. G. E. Synchronous Motor.

1—14″ Alberger Turbo Stand-by Pump driven by a Curtis Steam Turbine.

Pump House No. 3, known as Dam Pump, pumps water from the Lower Cooling Tank to the Upper Cooling Tank and consists of 2—20″ Alberger Double Suction Turbo Pumps 750 R.P.M., 10,500 gallons per minute against 27′ pumping head, each directly coupled to a 150 H.P., I. G. E. Synchronous Motor.

No. 2 Power Station was put into commission during the latter part of 1923 and is equipped with the most modern types of switches, choke coils and protective devices. Soon after this new plant was put into service it was found that the demand for power was continuously increasing and at present the 10,000 K.W. Sets are running at full load continuously and the average daily load often exceeds 16,000 KW. with peaks of 22,000 K.W. As there is no reserve power at hand it is proposed to install one single unit of 30,000 K.W. to cope with the situation.

	Power House No. 1	Power House No. 2	Total
Average Load 24 hours	4000 KW.	16000 KW.	20000 KW.
Peak Loads	4095 KW.	21500 KW.	25595 KW.
Load Factor	.76		
Power Factor	.8		

The power is distributed by means of overhead transmission and as these overhead lines have to pass through places subject to lightning and atmospheric disturbances special precautions have to be taken. A spot especially susceptible to lightning and the scene of frequent breakdowns until a system of earth curtain over transmission lines was erected to protect this area and thus a reasonable immunity against lightning stroke was secured.

General Organization

The prime object of the Electrical Department of any Steel Mill is to keep the Mill running with as few delays as possible to production. At the same time the protection of the electrical equipment against wear and tear, abuse and misuse, is of vital importance to the success of the Department. There are times, of course, when caution may be wisely thrown to the winds, and electrical apparatus sacrificed for a purpose, the end justifying the means, but these instances are very rare indeed, and extreme caution in the handling of equipment has been found more profitable.

The electrical organization is made up of two principal divisions, operating and construction. The operating end takes care of the operating and maintenance of all electrical equipment in all of the departments. There is also included the electrical Repair Division which embraces the electrical Repair Shop and Armature Repair Shop, with an organization of machines and electricians for handling all repairs connected with the electrical equipment. A new modern armature and repair shop with ample floor space, equipped with crane and a full line of tools is under contemplation. When this is accomplished, we shall be in a position to do all the necessary repairs more efficiently and economically than what we are doing at present for lack of room, up-to-date tools and labor saving devices. This electrical repair division has to undertake necessary repairs of the most up-to-date electrical equipment.

The construction division takes care of all new construction work from designing on down to installing and starting up of electrical apparatus.

The organization consists of a staff of 1,898 Repair and construction men, and 755 crane and controller drivers, making a total of 2,653 including the Chief Electrical Engineer and Assistant Electrical Engineers and Foremen.

The hearty co-operation of every one in this organization has made possible the complete success obtained at the Greater extensions, in the installation of the Electrical equipment without any outside help.

The limit of application of electricity in the Steel Industry has not yet been reached. Improved processes, new application and the ever increasing demands for more efficient operation will keep the Electrical Engineers of this Company always on the alert to meet new and exacting requirements.

The author desires to thank Mr. C. A. Alexander, the General Manager, for his kind permission to reprint the Works Photos. To Mrs. Biddle, personal Assistant to the General Manager, acknowledgment is made for her helpful suggestions in arranging the material and for assistance in checking and reading the proof.

Latest Practice in Hydraulic Valves

By DAVID BROWNLIE*

IT is hardly necessary to emphasize that one of the chief difficulties in connection with the use of hydraulic power, especially at the high pressures, so extensively employed in the iron and steel industries, is the operating valve. The main troubles, especially after considerable use, with the majority of designs are leakage and sticking, so that considerable force is necessary in the way of jerking and pulling at the control handle, rendering accurate and smooth control very difficult.

Accordingly therefore considerable interest attaches to one of the latest types of hydraulic valve, which will work at 3500 lbs. per square inch pressure and over without any leakage, and in fact is in use at 5,000 lbs. while it is available for any pressure. With regard to absence of sticking this valve in the smaller sizes, for pressures of 1000 lbs. or less, is easily controlled by the finger and thumb only, and the fact that no great force is required under all conditions of size and pressure is rendered evident because fixing down brackets for the valve are necessary, while other salient points are the ease of examination and repairs, and the ample water-way, which eliminates all throttling effect. The valve is made in two general types, the "double ported" and the "single-ported" in a number of standard sizes, in the latter case being ½" to 4" waterway and in the former ½" to 2". Some of the detailed dimensions as well as the weights of the standard sizes are given in table No. 1.

The principle of design is the same in both cases, and in the single ported type for example the body for most ordinary pressures is of gunmetal, bored out to receive two gunmetal spindles, one of which acts as a pressure valve and the other as an exhaust valve, the two spindles being coupled together at the top by a connecting lever and cross-heads. Midway between the two spindles on the lever, a pin and two side links are fitted, passing down the sides of the valve body to the under portion and connected together at their bottom ends by a gunmetal crosshead. To this crosshead is connected a small ram, the cylinder of which is bored out of the valve body, looking downwards: the hydraulic supply for this ram being taken from the inlet branch of the valve.

A constant downward thrust is thus exerted on the small ram, which is transferred through the side links and lever to the valve spindles. Also since the valve spindles themselves have pistons of exactly the same size at top and bottom and are therefore in equilibrium, the constant thrust from the small ram tends to keep the valves closed, while the valve lever is rounded at its outer end and fits into a recess formed in the cam plate on the operating handle, the rubbing surface being case hardened. For the highest pressure, however, the valve is made from a solid block of forged steel, with seats and spindles of nickel steel or other highly resistant alloy.

In operating, when the handle is moved upwards or downwards it moves the engaging end of the valve lever in the opposite direction and thereby raises one or other of the valve spindles, the one at rest on its seating **forming the fulcrum for the time being.**

If now the handle be raised or lowered sufficiently it throws the end of the valve lever entirely out of the recess in the cam plate so that it bears on the circumference of the cam plate and thus locks the

*Engineer, London, England.

Table No. 1

Dia. of Waterways.	SINGLE-PORTED VALVES					DOUBLE-PORTED VALVES				
	Overall Height.	Length over Flanges.	Overall Width.	Distance, center of Valve to end of Handle.	Approx. Weight in Pounds.	Overall Height.	Length over Flanges.	Overall Width.	Distance, center of Valve to end of Handle.	Approx. Weight in Pounds.
Ins.	Ins.	Ins.	Ins.	Ins.		Ins.	Ins.	Ins.	Ins.	
½	8⅛	5¼	4	9 5/16	18	11¼	6⅛	5	14⅛	65
¾	11	7¼	5¼	15¾	45	13½	7¼	5½	19⅝	112
1	12	8½	6	17	65	14¾	8¾	6½	22⅜	141
1¼	13¾	9¼	6¾	19¼	87	17¾	9¾	7½	24¾	210
1½	15¼	10	6¾	21¾	109	18½	10½	8½	27½	280
2	18⅝	12¼	7¾	24½	190	22½	13¼	9⅞	30½	450
3	24	16	11¼	33	259					

valve in the open position. Directly, however, the operator moves the handle back sufficiently to allow the valve lever to re-enter the recess in the cam plate, and as his hand is released from the handle, the small ram on the under side of the valve body brings both lever and handle to the mid position, thereby closing both spindles down to their respective

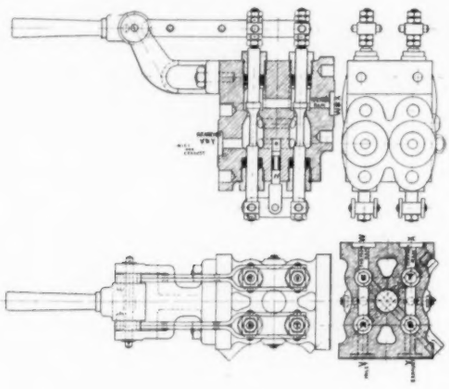

FIG. 1.

seats, the whole opertion being remarkably easy, as already indicated.

An illustration of the double ported valve is given below, and further with regard to the exact method of operation, when the valve handle is moved into the downward position the end of the valve lever is raised, as also the pressure and exhaust valves "R" and "S," the spindles "T" and "U" being down on their seats and acting as fulcrums for the valve levers. The pressure water, coming in through the branch "V" passes up through the valve "R" and across past valve "U," then away by branch "W" to one end of the hydraulic cylinder, the exhaust water from the other end of the cylinder coming into the valve through branch "X," past the valve "T" down through valve seat "S" and away to exhaust by branch "Y." When the handle is reversed, to the upward position, the valve lever is lowered and the valves "T" and "U" are raised, the spindles "R" and "S" forming the fulcrum. The pressure water in this case comes in as before through branch "V," and as valve "R" is closed, the water passes through the diagonal port across the chamber under valve "T," up through valve "T" which is open and so on to the hydraulic cylinder through the branch "X." The exhaust from the other end of the cylinder at the same time returns through the branch "W," down through valve seating "U," across to the diagonal port to the chamber underneath the valve "S," and so away to exhaust by port "Y." Finally it should be pointed out the small bearing down rams "H" for maintaining the valve spindles firmly on their seats by a constant downward thrust, draw their power water from the inlet diagonal passage by means of a hole drilled right through the valve body which is plugged at its outer ends.

The remarkable qualities of this valve, especially its ability to stand up to the most severe service constantly applied, is evident from results of quite recent endurance tests carried out by one of the principle hydraulic power users in U. S. A. A 1" valve was connected to their system for the control of a machine making 2500 to 3000 operations per 24 hours, and even after this service had been given continuously for months the valve when dismantled was as good as when it left maker's hands.

*Discussion: The Flat Suspended Open Hearth Roof**

By MEMBERSHIP

Discussion Presented at Buffalo in Connection With Inspection Trip to Donner Steel Co.

S. S. Wales†: Gentlemen. We have witnessed today a very interesting adaptation of mechanical engineering to the Open Hearth Furnace.

For as long as I can remember an Open Hearth Furnace, the old Arch Roof has held undisputed sway. I am not going to try to tell you any of my impressions of the Arch Roof or the Flat Roof, or whether I think the Flat Roof is better or not, because I know you will be told that by men here who know a great deal more about it than I do, but it does impress me as a very interesting advance that after all these years some one has had nerve enough to step out and abandon the old Arch Roof with its skewbacks, tie rods and buckstays which you had to tighten up or let out, and all the attendant troubles that all of you people know even better than I do.

The man who was instrumental in bringing this about, I am very proud to say, is the Chairman of our Combustion Committee. He really has this meeting in charge, and it gives me great pleasure to introduce Mr. W. J. Harper, Chairman of our Combustion Committee.

W. J. Harper†: Members of Combustion Committee and guests, I am very glad you were all able to meet here. We have a number of things to discuss, and when we have finished here we plan to go over to the Blooming Mill.

I would like to introduce the host of the day, Mr. J. W. Donner.

J. W. Donner§: On behalf of the Donner Steel Company, I am very glad to welcome the mem-

*Original paper appears in June issue of Iron and Steel Engineer.

†Chief Elec. Engr., Carnegie Steel Company, Pittsburgh, Pa.

†Steam Engineer, Donner Steel Company.

§Genl. Supt., Donner Steel Company.

bers of the Association of Iron and Steel Electrical Engineers here today, for the purpose of seeing our Plant and Open Hearth Roofs.

Let us go a little into the history of the development of this flat roof. It was necessary on our No. 2 Open Hearth Furnace, about a year and a half ago, to remove the top binding and replace these members with tie rods, and the question of putting in a suspended roof came up; so we decided to put in a suspended arched roof for our first installation. The results were so satisfactory that we went another jump and put on a flat suspended roof, which is really an adaptation of the flat boiler arch.

On the first suspended arch roof we got 245 heats, at which time we had to take the furnace off, not due to failure of the roof itself but to the fact that we had one or two spots where the roof was thin and got away from us, due to lack of replacement tile, so that the hanger casting let go before we knew it and the roof was in pretty bad shape.

The results on that were so good that we went ahead with the flat arch. On our present No. 2 Furnace roof we have to date, I think, 390 heats out, but we burned in a new bottom at the beginning of the run so there is an equivalent of about 415 heats on the roof as the Furnace stands today. We feel that we have not attained the last word in the performance of the flat roof. We feel that 500 heats is not too much to expect on the average.

There were numerous questions asked this morning as to the front and back walls. I might state that in locating the flat roof we placed the inside of the roof at the same elevation as existed at the crown of the old sprung roof, so that the front and back walls now, of course, are as high as the original peak of the arch.

On our old furnace, that is, the old sprung roof, we were getting normally about 80 heats on the front wall and about 67 heats on the back wall.

Under the flat roof as it now stands we have had three front walls and three back walls; the first front wall lasting 167 heats, the second 137 heats, and the present one has about 85 heats on it. The back walls are identical.

I do not know that there is any true explanation of this increased life of the front and back walls; about all we can say is that we have done it and that is the "proof of the pudding."

The next roof on No. 2 will probably be put in 3 or 4 inches lower. I believe we have gone as high as possible, and it may not be necessary to come down, but that will have to be experimented with to a certain extent.

As to fuel consumption, we have furnaces that are doing worse and some better, so I think the fuel consumption is about normal.

Time of heats to date is about 19 minutes faster than with the sprung arch, but in stating that, I must add that the furnace was completely rebuilt at the time the flat arch was put in. The reversing valves were changed from the Blair type to the Blaw-Knox, so I think the shorter time of heats cannot fairly be attributed to any one thing, but the point to remember is that the flat roof has not hindered the speed of the furnace, and, if anything, it has helped it.

If there are any questions to be asked, I am sure Mr. S. Muir, our Open Hearth Superintendent; Mr. William Stuart, our Mason Superintendent; or Mr. Harper will be very glad to answer them.

W. J. Harper: There is one explanation for the increased life on front and back walls. This is, that with the suspended roof we have relieved the pressure on these walls and have also reduced the velocity of gases passing them by increasing the cross-sectional area of the hearth. On No. 2 we have a flat suspended roof; on No. 1 we have a sprung suspended arch over the hearth; and on No. 10 we are installing a flat suspended roof, which is nearly completed. The time for installing this roof was 45 mason hours, not including time for helpers. The flat roof we put on No. 2, being larger than the roof on No. 10, required about 1300 more blocks. The time on No. 2 roof was better than 100 mason hours, which indicates that we are becoming more familiar with installing roofs of this type.

G. R. McDermott§: I was particularly interested in coming to Buffalo to observe the flat suspended roof installed on an open hearth furnace and have really nothing much to say except that some four or five years ago Mr. Naismith of our Company and myself were of the opinion that it had possibilities, both from the standpoint of fuel economy and maintenance. I desire to take this opportunity in expressing my congratulations to the Donner Steel Company in taking the initiative of installing a flat suspended roof on an open hearth furnace. It is true that suspeded roofs have been installed on open hearths but they have all been curved.

For steam boilers the flat suspended roof has been in use for a number of years, in connection with mechanical stokers with beneficial results from the standpoint of combustion and maintenance and I believe that its adaptation to the open hearth is a step in the right direction.

As you have explained it is your intention to experiment in lowering the roof, i. e., the distance from the fore plate to the under side of the roof, I believe from our own experience with sprung roofs the lowering of the flat roof may be done with beneficial results, but naturally, of course, you are justified in proceeding with caution.

W. P. Chandler, Jr.*: I think the Donner Steel Company is to be congratulated in taking this forward step in the development of Open Hearth construction.

The flat arch design has proven itself as Mr. Harper and Mr. McDermott have said, in other fields of combustion engineering, particularly where a uniform distribution of heat across the entire surface is desired. Such a case is exemplified by the coke breeze burning stoker. In this instance ignition is the difficult problem and the flat arch has done much towards solving the difficulty.

In the Open Hearth the heat should be distributed across the whole bath of the furnace and not concentrated in the center, as is the tendency with a sprung roof. Especially in view of the tendency toward chilling of the bath with cold air drawn into the furnace around the charging doors. The flattening of the roof tends to force a greater amount of heat to enter the bath close to the front

§Asst. Chief Engr., Illinois Steel Co., South Works.

*Engr., American Heat Economy Bureau, Pittsburgh, Pa.

wall of the furnace and has undoubtedly resulted in a faster working furnace.

Another point mentioned in the discussion was the height of the roof. The factors involved in heat transfer are temperature difference and quantity of heat. The temperature difference may be maintained the same for either type of roof, but the quantity of heat which is dependent on the quantity of gases in the furnace is greater in the case of the flat roof as installed. Heat is radiated from the layer of hot gases passing over the bath and if this layer can be increased in depth, the amount of heat transmitted will be increased.

I wish to thank everyone concerned for the privilege of being present on this occasion and of having the opportunity of listening to the discussion concerning the flat roof.

R. L. Leventry*: Our experience on coke gas and tar furnaces has been that when we raised our skew back from 52" to 60" we raised our roof life, but lowered the life of the front and backwall.

When I saw this furnace with skew back 84" high, my first thought was that the life of the front and backwall must be extremely low.

After hearing the history of this furnace which shows the front and backwall life over 150 heats, I admit I was mistaken, although our experience has been to the contrary.

Any furnace which makes over 400 heats on the roof with coke oven gas and tar as fuel is out of the ordinary.

It is interesting and I am glad that I have had this opportunity of seeing it.

C. B. Collingwood‡: Then your results show that you have doubled the life of the front and back walls of this furnace as compared to when you had a suspended arched roof and old type sprung roof.

R. L. Leventry: I do not think the weight ought to have anything to do with the life of the front and back wall.

C. B. Collingwood: Do you think keying up a backwall too tight would have anything to do with a short life?

R. L. Leventry: I think it possible but I cannot explain how the flat roof has doubled the life of the front and back walls; perhaps Mr. Muir can answer that.

Samuel Muir†: That is pretty hard to answer, owing to its being the first installation of a flat roof on an Open Hearth Furnace; although my opinion is that the increased area inside the furnace has helped the life of the front and back walls considerably. At all times we have had no difficulty controlling the flame. Our port is about four inches off center towards the front wall, which, so far, has been satisfactory.

C. B. Collingwood: What is the overall length of your furnace? About eighty feet?

S. Muir: The length of the furnace is seventy-five feet. (Checked by Mr. Foell.)

C. B. Collingwood: No doubt the pressure on the back wall results in lower back wall life.

S. Muir: On the first back wall we started off with eighteen inches thick to a height of two feet, stepping off to a thirteen inch wall to a height of two feet, finishing up from that point with a nine inch wall.

C. B. Collingwood: Is that what you have now on your No. 10 Furnace?

S. Muir: Yes.

C. B. Collingwood: May I ask a question to clear up a point on the wall carrying weight? Your old type roof was suspended from the skewback channels? In replacing your front and back walls the roof was still held in suspension?

S. Muir: Yes.

C. B. Collingwood: The point I am clearing up is: There is actually no weight on the walls?

S. Muir: The only weight the wall is carrying is the weight of the brick work it is built of, there being no keying up, as there are no skewback channels needed in the installation of this roof. The opening between the back wall and the roof is sealed by placing a loose brick on top of the front and back wall, and grouted in after a few heats have been taken out of the furnace.

C. B. Collingwood: After your furnace is completed, how far is the back wall from the roof?

S. Muir: The back wall is built up to within one and one-half inches of the roof, the loose brick on top of the walls making the seal. Should the front and back walls expand enough to come in contact with the roof, no serious results would occur, as the outside brick is suspended with a small individual casting.

Samuel Naismith‡: I did not expect to say anything at this meeting today, but I think that a flat suspended roof is a big improvement over an arched roof, and the Donner Steel Company is to be congratulated on making this experiment. As we all know, a flat roof has shown an improvement on all kinds of reheating furnaces, and I think the same results will show up in Open Hearth practice.

In my estimation the roof looks a little high.

The spalling that takes place occasionally on the arched roof is overcome by the use of the flat roof, and in the future we hope to see more experimenting along these lines.

C. B. Collingwood: How high is your suspended roof from the sill plate?

S. Muir: It is seven feet one inch from the sill plate.

S. Naismith: Does the flat suspended roof burn out as fast along the skewback as the old type arch roof, as it looks to be burned thinner at that point?

S. Muir: The reason that Mr. Naismith thinks the roof is being scoured out long the skewback is due to the fact that we had a patch put in the middle of the roof about four feet from the back wall, the original brick along the skewback showing the wear against the new.

When installing the roof, a discussion came up as to how high the flat roof should be placed above the sill plates, and owing to its being an experiment we decided to suspend the roof the same height as the crown of the arch on our present sprung roof practice.

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*Supt. O. H. Dept., Republic Iron & Steel Co., Youngstown, Ohio.

‡Supt. of Open Hearth, The Stanley Works.

†Supt. of Open Hearth, Donner Steel Company.

‡Supt., Mason Dept., Illinois Steel Company.

Some discussion took place as to lowering the roof which we have just recently installed on our No. 10 Furnace, and I contemplated lowering it six inches. The final decision was to put it on the same as our No. 2 Furnace, so as to compare it with the furnace practice, especially in time of heats and fuel consumed.

C. B. Collingwood: When charging up, using light scrap, do you have any trouble with the flame spreading and burning the front or back wall?

S. Muir: Our experience along these lines has been a more even distribution of flame through the furnace while charging.

C. B. Collingwood: Will four hundred and fifty heats pay for itself?

S. Muir: As far as prices are concerned, I would not like to go into this, as these figures are available at the M. H. Detrick Company. If we get four hundred and fifty heats out of these roofs we will consider the roof a good proposition.

G. R. McDermott: Would you advocate putting in a longer brick in the balance of the roofs?

S. Muir: I do not see where it is necessary.

C. B. Collingwood: You say the brick along the skewback are not burning out so rapidly, for at least three feet from the skewback?

S. Muir: Your arched roofs generally cut out the back wall eighteen to twenty-four inches and probably ten to fifteen feet on either side of tapping hole. On the present installation of the Detrick flat roof on our No. 2 Furnace the original brick are still intact along the skewbacks, which shows for itself that the scouring at this point is a great deal less than on the arched roof.

C. B. Collingwood: Do you think you have left enough room for expansion on your No. 10 roof?

S. Muir: We had not much trouble with expansion, although we put some silica sand on top of the front and back wall for a seal, which fluxed and gave us a little trouble, due to our own fault.

G. R. McDermott: If you got four hundred heats out of a sprung roof, would the flat roof pay for itself, if there is no fuel economy?

S. Muir: What thickness of roof do you refer to?

G. R. McDermott: An eighteen inch roof.

S. Muir: From our experience with a flat roof as compared with our arched roof, I would not hesitate in recommending an installation of a Detrick flat roof, both roofs being of equal thickness.

C. B. Collingwood: What life did you get off the sprung roof?

S. Muir: About two hundred heats.

C. B. Collingwood: You have at least doubled the life of your roof?

S. Muir: Yes. You all understand that this is a fifteen inch brick, three inches of which is used in hanging it upon the casting, leaving twelve inches for erosion.

C. B. Collingwood: Do you think an eighteen inch roof would be any improvement?

S. Muir: I would not like to say.

Question: Is your roof giving out before the rest of the furnace?

S. Muir: No, we have to make slight repairs on the ends.

Question: How about checkers and slag pockets?

S. Muir: We clean checkers and slag pockets after a run of two hundred heats.

Question: How many brick were put into the roof for the run of four hundred heats?

S. Muir: Approximately seventeen hundred brick. This was due to an experience of patching this roof after a two hundred heat run.

Question: You have not a sloping back wall on No. 10 Furnace?

S. Muir: No, but we will probably try this out later.

W. J. Harper: Our average roof life for the year 1926 was 192 heats. On No. 2 furnace, however, we were much below this figure—approximately 145 heats. It is perfectly obvious that if we are able to get 400 heats on the present No. 2 roof we are well justified in adopting this type of construction. There are additional advantages due to flat suspended roofs: (1) Open Hearth Department is relieved of having a roof fall in on a heat. This is very important, especially when we are making an alloy heat. (2) Increased life on front and back walls. (3) Able to maintain the furnace in operation a greater length of time.

Both No. 1 and No. 2 Furnaces were originally of the tilting type and were reconstructed into a stationary furnace in 1917. The rigid construction that was on both of these furnaces is no doubt the reason for the poor roof life. Due to this short life the question arose as to whether we should remove the rigid binding and install tie-rods or else adopt a suspended type of roof. In either case the cost of reconstructing the binding was practically the same, so it was decided to adopt the suspended type of Open Hearth roof.

H. B. Hubbard§: I think you have pretty well covered the subject. I do not think of any additional questions.

W. J. Harper: If there is not further discussion we will now adjourn and go over to the Blooming Mill, where we would like to show you our new Recuperative Soaking Pit Furnace and our Motor Drive Room.

Discussion Presented at Pittsburgh

L. Quigg*: What was the fuel ratio of tar and gas that was used on that furnace; the percentage of tar and gas?

W. J. Harper: At Donner Steel Co. we sell coke oven gas so that the ratio will vary from 10% to 80% gas.

L. Quigg: What was the time of heats?

W. J. Harper: 11 hours and 30 minutes, heats of 100 tons; charge to tap.

L. Quigg: 12 hours and 30 minutes tap to tap.

W. J. Harper: Yes.

L. Quigg: Has the melting time, that is the time it takes from charge to melt, appreciably increased?

W. J. Harper: No! It is about 7 hours.

L. Quigg: You are operating at about the same rate as on sprung roof?

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§Supt., O. H. Dept., Inland Steel Company.

*Open Hearth Supt., Bethlehem Steel Co., Johnstown, Pa.

W. J. Harper: Yes.

L. Quigg: When operating with as high as 80% coke oven gas, did you have trouble in holding the gas down and did not the roof suffer?

W. J. Harper: No.

L. Quigg: Where you operate on producer gas, more by precedent than anything else, we are inclined to think the arch of the roof has a tendency to govern flame travel and to reflect heat towards the center of the bath. Do you think the flatness of the roof would tend to permit gas, particularly early in the heat, to play unduly on the front or backs?

W. J. Harper: I don't believe so.

L. Quigg: How do the comparative costs stack up? In other words, the only reason we aim to improve a practice is to decrease the cost. How would you say a suspended roof would compare in cost with a regular type of reinforced roof; a ribbed roof operating 250 heats with minor patches, would that compare with 425 heats in suspended arch in cost?

W. J. Harper: What is you cost per ton on a ribbed roof?

L. Quigg: The cost per ton in any one shop is pertinent to that shop; some running lower than others. I am only asking for the relation of your costs.

W. J. Harper: We have lowered cost per ton with the flat roof.

L. Quigg: You would recommend the installation, and have you recommended the flat roof in preference to arch roof suspension?

W. J. Harper: Yes, sir.

L. Quigg: You propose carrying out your plan and installing flat suspension in preference to the arch roof?

W. J. Harper: Yes.

L. Quigg: Would you deem it feasible to increase the depth of that brick. You started with 12". If the theory is right, would it not be possible to use 15" or 18" of brick?

W. J. Harper: You will no doubt encounter more spawling.

L. Quigg: Due to the suspension members, would the radiation be less rapid than in the construction permitting the air to circulate freely?

A. L. Foell*: The radiation is probably more rapid, due to the metallic contact with the hangers which will help in carrying off the heat.

L. Quigg: If covered with steel bindings which in turn prevent the passage of air over the roof, it is possible that spalling and cutting would be more severe than in the sprung arch type. Did you encounter undue cutting or spalling?

W. J. Harper: We retiled a portion of the roof but the original tile are still in along the skewback.

W. Trinks†: Is it possible in suspended roof to use special brick such as chrome? Silica is a poor excuse in a basic furnace, but we have to use it because it holds its strength. In a suspended roof we don't get the terrific crush at the bottom, and in a suspended roof that is not essential, so it may be possible to use a material that is neutral such as chrome?

*Chief Engineer, Donner Steel Co., Buffalo, N. Y.

†Prof., Mechanical Engineering, Carnegie Tech.

A. L. Foell: We haven't tried chrome brick as yet. The only trouble I can see to its use would be the heavy expense of this material.

Walter Kelly* I was interested in the comparison of the cost of the brick. I roughly estimated with sprung roof of the size furnace you have the brick would cost about $990, and the brick with the suspended roof about $1856. Do you get a life of brick sufficiently long to justify the difference?

A. L. Foell:. When you consider that we averaged only 132 heats as against 425, I think that answer's Mr. Kelly's question.

L. Quigg:. Would you attribute the saving entirely due to the flat roof? Isn't 132 extremely low?

A. L. Foell: Yes. One hundred and thirty-two heats is admittedly extremely low and as explained before was undoubtedly due to the rigid binding. It was cheaper for us to install the flat suspended roof than to change the entire furnace binding in order to effectively apply tie rods.

W. P. Chandler: The development that has taken place in the open hearth design and operation in the last few years is probably the first step that will finally bring the open hearth furnace up to the equivalent of our present blast furnace operation. We have a rather efficient unit where we are making pig iron and a rather inefficient unit where we are making steel and principally all the engineering developments which have taken place have been in the blast furnace. The flat roof and several other propositions that have been brought out for application to open hearth probably mark the first step in this development that will eventually give us a real efficient unit in the steel making business. Our fuel value has increased until it is pretty far up in the air. They are not down where they belong in any sense of the word and a great deal can be done to cut those fuel values in half; and I have no doubt that is the story we will hear if we come back in five or six years and talk this thing over again.

R. S. Shoemaker†: I would like to ask Mr. Foell if he thinks it would be an advantage to have a sloping back wall with flat roof.

A. L. Foell: I might answer that in this way: When Mr. Nasmith of South Works saw the flat roof, he immediately said that roof would work well with his sloping back wall. I might add we have a sloping back wall on No. 5 furnace, and I think as soon as we can get to it, we will have a flat roof on it also.

Mr. Nichols‡: The increase in the life of the roof 132 to 450 heats is purely remarkable, and that gave rise in my mind to the thought as to why is one so low and the other so high. Our experience is about 250 heats with sprung arch roof, changing roof and some burners; changing burners, ports and up-takes, 340 heats; only one as high as 400. However, we did not figure it paid to extend the life to 400 heats, inasmuch as the fuel cost was so high, that any economy in building was wiped out. I think it would be interesting to know the fuel used on the old roof and whether the total economy is due to the flat roof or some other change in the fur-

*Bethlehem Steel Co.

†Supt. Maintenance, American Rolling Mills Co., Middletown, O.

‡M. M., Edgewater Steel Co., Oakmont, Pa.

nace. Also we found that about 350 heats was a maximum, inasmuch as it would be stopped up with flue dust and deposit from tar. I would like to ask what the B.t.u. per ton of steel will be with flat roof?

A. L. Foell: About 6,000,000 B.t.u. per ton of steel on this particular furnace.

J. S. Green: At what particular spot of the roof was the hot patch made?

A. L. Foell: Right over the burner.

J. S. Green: Due to local condition or nature of the brick?

A. L. Foell: The first patch was after 267 heats and that was due to the starting up of the furnace. About 8 brick spawled and we sent the brick back to the manufacturers who replaced them.

J. S. Green: Were not castings warped so they could not be used again; or is it possible if you pull out the key brick, to replace the casting as a unit?

W. J. Harper: We burned out 100 castings in the run.

J. S. Green: The maintenance appeals to me. The hook has bolt and clamp on the I beam. It seems to me Mr. Foell's remarks brought out that perhaps the roof will never go down for a new whole roof. If it is going to be hot patched, consideration should be made for quick clamp on hook that you can reach in with a bar. It seems to me if it is going to develop into hot patching, we ought to devise some quick means of doing that.

W. J. Harper: We are working on an arrangement now that will help us considerably.

A. L. Foell: In the matter of replacing the roof, I do not believe it will eventually be replaced by hot patching. Rather this; the portion over the bath will undoubtedly get the most severe punishment, and I have noticed it is the portion over the bath that actually does get the most severe usage and requires replacement oftener. If the portion over the hearth is replaced the slope over the ports may be allowed to stand until these require renewing. It will therefore never be necessary to replace an entire roof from end to end.

L. Quigg: Do you have a count on the brick you replaced?

A. L. Foell: Approximately 1900 tile.

L. Quigg: How many in the arch roof?

A. L. Foell: 4900.

L. Quigg: The most satisfactory way we have found to figure roof life has been to divide the number of brick used on the roof during the entire run by the number of brick required for building one roof, then dividing the number of heats made on run by this figure. Using this method with your figures, the performance is 307 heats.

W. J. Harper: Is the number of heats a real indication of the life of brick? Isn't it possible to figure the fuel burned under a roof? The time of heats varies, and brick won't wear any faster in one shop than another.

W. Trinks: If you want to drive a furnace, then you have to have high temperature. Then you may have it very high and the time that you burn the roof very short. With hot flame I have seen a roof burn out in 20 hours, and not much fuel used as compared to long run. So that it won't work.

W. J. Harper: Is there some way we could get together on what is roof life, so it would be more or less standardized. In some shops they are making heats in 7 or 8 hours; our shop 11 or 12 hours is not comparable with shops making heats in 7 hours. We have been checking up on roof life, and furnaces using as fuel coke oven gas, we have found that the average life is much less than with producer gas.

Walter Kelley: It was stated it is easier to repair this roof than sprung arch. He stated delays were 39 hours. You can put in a good many main rows in 39 hours.

W. J. Harper: You would have more delays on the furnace with a sprung roof due to the time required for cooling off and lighting up the furnace.

Mr. Nichols: The figure of 6,000,000 B.t.u. per ton of steel, is that gross or not?

W. J. Harper: Gross tons.

Adventures in Lubrication

By H. M. LUDWICK*

THE lubrication of machinery is a subject which should receive the careful thought of the engineer. There are many methods of application for oils and greases, but the most common practice has been the use of oil through various types of sight feed oil cups.

During my experience of more than seventeen years in the maintenance of machinery I have tested a great many kinds of lubricants and methods of application. For a number of years we used oil practically throughout the plant and it may be of interest to plant operating men to note the methods used in the elimination of some of our lubricating troubles.

*Formerly Master Mechanic, Parkesburg Iron Company, Parkesburg, Pa.

Wandering Oil

In the operation of our welding furnaces, the driving bearings of which were lubricated with oil in ring type bearings we were faced with constant trouble due to the thinning down of the oil and the consequent spillage and oil soaked condition of the units and the surrounding floor. In fact the oil would work down into the foundation and cause the bed plate to loosen. Upon several occasions, fires resulted from sparks from the furnaces igniting the oil soaked surfaces and upon two occasions 200 H.P. motors were destroyed and the babbitt in the machine bearings was melted.

The Dust Menace

Another difficulty we had was due to the dust from the furnace getting into the bearings and caus-

ing the ring to stick and preventing it following the shaft. This would result in hot bearings with the attending loss of production due to shut-downs.

We tried the use of grease in hand compression cups and while this eliminated the loss and leakage of lubricants and got rid of the oil soaked condition previously noted, we still experienced trouble due to the crossing of threads on the grease cups. Some of the bearings were in places difficult of access and the oilers would not turn the cups as frequently as necessary. We then adopted the Keystone Safety lubricator and it was a simple matter to maintain a supply of grease at the bearings. All of our previous trouble was eliminated.

It was a common occurrence for the tube mill journals to come out worn uneven and badly scored due to lack of lubrication. This condition would cause the mills to become out of line and result in "stickers." With the use of grease applied under pressure the journals were maintained in good condition and the mills were kept in line and better work was turned out, also in increased quantity. The worn journals would cause a knock and the vibration was very hard on the motors and the wires would become broken.

When oil was used it would splash on to the pinions and make it hard to keep gear grease on them as the oil would tend to wash it off. Frequently oil would splash into the motor and cause a short circuit. The natural vibration was severe enough to cause oil cup breakage and as the bearings became worn this vibration would increase so that it was practically impossible to keep a cup on the bearings.

We had considerable trouble in cold weather with the flow of oil stopping, and it was necessary for the oilers to go around with torches to warm up the oil cups. Often a torch would be placed alongside a cup and the oilers would walk away. The oil would thin down and the cup would empty itself and the bearings run without lubricant.

A good grade of petroleum lubricating grease which is not affected by normal temperature changes overcome this trouble.

The Oiler "Turnover"

We had considerable trouble keeping oilers on the job because the work was so sloppy. No one wanted it and the frequent change of oilers would cause a lot of trouble. This condition was changed after the installation of the pressure system and we had very few changes in our force after that time.

With oil cups it was hard to know just how many drops per minute to feed to the bearings and the oiler would adjust the cup and go away. Probably before the next round the cup would empty. If a hot bearing did not occur, the fact that the journals had been running for several hours without oil would cause unnecessary wear. With the use of the grease system there was always a supply of grease in or at the bearings and even though some time may elapse between application of pressure there would be enough vacuum created by the turning shaft to draw grease into the bearings.

Lubricating From the Bottom Up

One of the hardest units to lubricate was the cold scarfer. The average life of a bearing on this machine was around two weeks. After equipping the unit with the lubricator, and using a heavy bodied grease, the bearing life was lengthened from six months to a year. Some of the bearings ran 18 months. The power load on the unit was cut down 25 to 30%.

Before we used grease we had trouble with breakage of rolls. The broken roll would be caused by bearings wearing out of line and throwing all the load on one point in the roll. The oil was applied to the top of the journal and it was hard to have it carried around to the bottom of the journal, the point of highest pressure. When we applied the lubricator we forced the grease in from the bottom right at the point of highest pressure where it was most needed and by keeping the journal supplied with a film of lubricant we got rid of the trouble of broken rolls.

Eliminating Short Circuits

The finishing mill was driven by a 50 H.P. reversible motor equipped with ring oil bearings. Every time the motor would reverse it had a tendency to lift the shaft bearings and it would splash oil into the fields and the armature and regularly cause short circuit due to oil contamination. It was only a question of a short time until the armature would have to be rewound.

We ran a lead line from the lubricator which was connected to the finishing mill over to the motor and after fitting the motor shaft with babbitted sleeves and connected the lubricator pipes to it this completely eliminated lubricant contamination of the windings and got rid of the oil saturation on the outside of the motor and increased the bearings life 50%.

We had considerable trouble with the oil ring bearings of the cold saws becoming overheated causing frequent stoppages. The oil would splash into the motor and also on to the driving belts, resulting in motor trouble and shortening the life of the belt. These unfavorable conditions were overcome by the application of the grease pressure system.

Letting "George" Do It

We operated a masher testing machine, the bearings of which had to be repaired every month. After adopting the grease lubricator these machines would run from a year to 18 months without any repairs. Some of the bearings were 10′ above the floor and oilers would often neglect these hard-to-get-at bearings. With the constant presence of grease the bearings were lubricated at all times and by thus saving bearing wear, vibration was kept to a minimum. Sometimes excessive vibration would wear the thread off the bolts that held the bearings and the cap would work loose and increase our troubles.

For many years we worried along with the use of oil in the Tilting Cold Saws. This was overcome when grease was applied.

We experienced the usual troubles in the operation of our electric traveling cranes, with the use of grease cups, making it necessary to go to each bearing. Time and again the bearing that was hard to reach would be neglected and cause trouble. One operator would say, "I'll leave this go for the other fellow" and the next operator would do the same thing and before they knew it the bearing was gone. We had always followed the practice of either having the operator himself or an oiler go over the

crane and while lubricating each bearing make an inspection of the equipment. This was considered to be the safest practice so that all parts of the crane could be regularly inspected. We found, however, that depending upon the human element was a costly system and time after time bearing trouble would develop and it could be noted that the bearing has not been lubricated for several days or longer. On the other hand you would line up the fellows who were responsible and none of them would want to assume the responsibility for such bearings failures and probably would blame it on the mechanical department or say that the oil or grease was no good. After all, I found that the use of the pressure system was better than so-called "inspection trip" as the grease would take care of the bearing at all times.

2 Lbs. of Grease vs. 12 Gallons of Oil

I had an interesting experience in connection with the lubrication of a Hot Billet Shear in a steel plant. On this particular shear handling billets up to 11"x12" they were using 10 to 12 gallons of cylinder oil every ten hours and were having constant trouble with heated bearings and splashing oil soaking the wires and running down in their electric conduits with resulting motor trouble. This unit was changed over to grease with the pressure system and they are now using 2 lbs. of grease in 10 hours and have no bearing trouble and the unit is in a clean condition.

Items of Interest

The Lo-Hed Hoist Division of the American Engineering Company announces the appointment of direct factory representatives in Pittsburgh and Cleveland for the sale of its Lo-Hed mono-rail electric hoists.

The Pittsburgh office, whose territory will include Western Pennsylvania, West Virginia and counties along the Eastern border of Ohio, is located in the Oliver Building with Mr. D. A. Polhemus in charge and Mr. John Kaiser assisting.

Mr. W. C. Minier will direct sales in Northern Ohio, except for territory surrounding Toledo, with offices at 2195 Bellfield Avenue, Cleveland.

The Sixth International First-Aid and Mine Rescue Contest, held at Pittsburgh, Pa., August 30 and 31 and September 1, under the auspices of the United States Bureau of Mines, Department of Commerce, was the most successful of these important annual mine-safety events so far conducted. The contests were participated in by 47 first-aid teams and 18 mine-rescue teams, comprised of approximately 300 miners skilled in these humane practices. The first-aid teams were from 13 states as follows: Arizona, California, Colorado, Illinois, Indiana, Kentucky, Louisiana, Maryland, Montana, Pennsylvania, Utah, Virginia, and West Virginia. The mine-rescue teams were from six states, viz: Arizona, Illinois, Maryland, Pennsylvania, Virginia, and West Virginia. Four of the teams were from metal mines, two being from Arizona and one each from Utah and Montana. Two teams, from California and Louisiana, represented the petroleum industry. The remaining teams were from coal mines.

A new type of tinplate truck has recently been put on the market by the Baker-Raulang Company of Cleveland, Ohio. This truck has a capacity of five thousand pounds of sheets and is so compact that it may be driven inside the average box car.

The driving axle is of the full floating type with 17½ to 1 worm gear reduction. The Baker series type driving motor is mounted on a cradle which is cast integrally with the axle housing, thereby insuring perfect alignment between the motor, worm, and worm wheel. In order to provide easy steering, the knuckle pivots are in line with the tire centers. Trailing axle is machined from forged alloy steel and the wheels turn on individual knuckles with the pivots also in line with the tire centers.

The controller is the standard Baker all-metal type with renewable segments and renewable finger tips. An automatic switch of the quick break type with auxiliary carbon contacts is provided as a safety feature. It is interlocked with the controller and prevents the operation of the truck except by a conscious and sustained action on the part of the operator.

The hoist consists of two drums either of which may be driven by a series wound motor. A selector switch operates a set of magnetic clutches and determines which drum will be driven when the power is applied. One cable hoists the carriage and forks while the other tilts the super-structure. When picking up a load, the super-structure is normally vertical and the forks will lift high enough to stack loads one upon the other. The super-structure may be tilted a little forward of the vertical position in order to bring the points of the fork prongs into contact with the floor.

Limit switches are provided to open the hoist motor circuit at both limits of travel of the carriage and of the super-structure.

A motor so small its rotor could be wrapped in a postage stamp is used by the Westinghouse Electric and Manufacturing Company, for timing the OB watthour meter demand register. It is the smallest synchronous motor ever manufactured for practical use. Four million of these complete motors, together with their reduction gears, would be required to balance a large 8,000 hp. motor recently built in the Westinghouse shops. The diameters of their shafts are in the ratio of 512 to 1. The rotors are still smaller in proportion as 37 million are required to equal the weight of the large one. While two men, one on the other's shoulders, could stand upright in the circular opening for the rotor in the 8000 hp. motor, the rotor of this motor could be worn, set in a ring, on a man's little finger.

Mr. Alfred Alsaker, Chief Engineer of the Delta-Star Electric Company, Chicago, Ill., sailed Septem-

ber 11 for a six weeks' visit to Norway, France and Italy to investigate high tension developments on the Continent.

International Combustion Engineering Corporation has announced the acquisition from Sulzer Brothers, Winterthur, Switzerland of the Sulzer System for dry quenching coke which will be developed in this country by a new subsidiary, Dry Quenching Equipment Corporation.

The Sulzer System is widely used in Europe for cooling coke without the use of water. Steam is produced for power and plant purposes during the cooling process, thus diverting to useful work the sensible heat of the coke, which is at present lost by wet quenching.

The first unit in America was installed by Sulzer Brothers for the Rochester Gas & Electric Corporation where the equipment is exceeding the manufacturer's guarantee in daily operation.

Announcement has just been made by the G. H. Williams Company, that H. B. Ackland has been appointed manager of the New York territory, with offices at 30 Church Street, New York City.

Another addition to the G. H. Williams Company's field staff has been effected by the appointment of C. F. Weiblen as direct factory representative in the Ohio district with headquarters in Cleveland.

The Graybar Electric Company announced last week the appointment of Mr. H. B. Bibb as Sales Manager of the Graybar Norfolk Branch House.

At the same time the promotion of Mr. E. W. Thurston to Assistant Telephone Sales Manager was announced. Mr. Thurston will now be located at the executive offices of the company in New York.

The Westinghouse Electric and Manufacturing Company has just issued a complete catalogue of industrial electric heating apparatus, designated as Catalogue 25. Twenty-seven different types of equipment are listed, including box furnaces, lead and salt baths and pots, pit, rotary hearth and pusher furnaces, special furnaces and ovens, drawing baths and ovens, baking ovens, laboratory furnaces, strip heaters of all classes, automatic melting pots, control equipment and accessories. For the standard furnaces and ovens production curves are given which enable one to estimate accurately in advance the kilowatt hours required to turn out a certain amount of steel when heated to a definite temperature. The publication is profusely illustrated to show the various apparatus and its construction.

The Clark Controller Company of Cleveland, Ohio, have added to their Sales Organization by appointing W. H. Kingsley as their direct representative in New York City, working in conjunction with Mr. K. I. Clisby, with offices at 74 Trinity Place, New York City.

Mr. G. L. Fisk has been appointed Chief Engineer of the Mesta Machine Company, Pittsburgh, Pa. Mr. Fisk was formerly Chief Engineer of the Pittsburgh Crucible Steel Company, Midland, Pa., which position involved charge of engineering, construction and maintenance for the Midland Plant, as well as of major engineering projects and installations made by the Crucible Steel Company of America.

After his education in Sweden he became associated with Cambria Steel Company and later served as Resident Engineer for Julian Kennedy, Sahlin & Company, Ltd., during the construction of the Tata Iron & Steel Company of India.

The Trumbull-Vanderpoel Electric Manufacturing Company of Bantam, Conn., manufacturers of TV Safety Switches are prepared to furnish their new line of Current Breaker Safety Switches in cast iron boxes for use in steel, flour, cement and other mills of this type, mines, railroads and in fact for any industrial purpose where dust-proof, water-proof and fume-proof Safety Switches are necessary.

Harnischfeger Corporation announce the establishment of two new agency agreements:

Johnson-Beckwith Equipment Co., 524 Union Davenport Bank Building, Davenport, Iowa, will represent the Corporation in the Davenport territory; and the Northwest Equipment Co., Billings, Montana, has just been assigned the Montana territory. These new agencies will handle the complete P & H line of Gasoline, Diesel, and Electric powered Shovels, Draglines, Clamshell Cranes, etc.

Harnischfeger Corporation announce the opening of a new branch office at 524 Buder Building, St. Louis, Missouri.

Mr. L. J. DeHoney, Sales Engineer, will direct the work in the St. Louis territory.

The Cutler-Hammer Mfg. Company announce that their Cleveland Office has been moved from the Guardian Trust Building to the Guarantee Title Building, Suite 1905. The new office has approximately three times the space of the old with increased facilities, made necessary by the large and growing business.

The new plant of the Canadian International Paper Company at Three Rivers, Quebec, is indicative of a growing tendency on the part of large industrial plants to build power plants that are the equal in efficiency and modern design of the leading Central Stations.

A description and illustration of this plant are presented in a pamphlet just received from the printer, and is available to all those who request it from the Combustion Engineering Corporation.

The Celite Products Co. has just issued a new bulletin, No. 107, on "Heat Insulation in the Iron & Steel Plant."

This bulletin contains drawings showing the latest approved methods of insulating blast furnace stacks, bustle pipes, mains, and stoves; open-hearth regenerators and flues; producer gas mains; coke ovens; boilers; soaking pits, and various types of reheating furnaces. Copy may be had upon request.

Mr. R. H. McGredy has been appointed Sales Manager of the Lo-Hed Hoist Division of the American Engineering Company, Philadelphia.